UNIVERSITY OF CALIFORNIA PUBLICATIONS

IN

GEOGRAPHY

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EDITOR

VOLUME I

WITH 55 PLATES

UNIVERSITY OF CALIFORNIA PRESS
BERKELEY
1913-1917

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY

Vol. 1, No. 1, pp. 1-60, pls. 1-11 April 8, 1913

THE RUSSIAN RIVER

A CHARACTERISTIC STREAM OF THE CALIFORNIA COAST RANGES

BY

RULIFF S. HOLWAY

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INTRODUCTION

The rivers of the Coast Ranges of California exhibit many striking peculiarities of drainage. the explanation of which would materially aid in the interpretation of the recent geomorphic history of this region. A mere glance at the drainage map is sufficient for a student of physiography to note unusual relations of tributaries to trunk streams and striking changes in river courses that at once suggest a drainage system which is far from the simple pattern developed upon a recently uplifted and homogeneous land mass. More careful study shows that these departures from normal types are common in minor streams and tributaries and that there probably exists in the Coast Region of California the maximum variety of stream adjustment to diastrophic changes and to underlying structure. These marked instances of stream development have challenged the attention of many workers in the earth sciences and frequent references to special instances with more or less hypothetical explanations are to be found not only in scientific literature but in ordinary descriptions of travel. The limited amount of serious study in so rich a field is due in some part to the wealth of unsolved scientific problems in California, but the fact may also be explained largely by the scarcity of topographic maps in the coast province and the still greater lack of available data concerning the areal geology.

The writer in offering this study of Russian River as an interesting example of the drainage problems of the California Coast realizes fully the difficulty of determining the exact truth in working under the limitations noted above, yet the results are of such interest and bear indirectly upon so many Coast Range problems that it does not seem advisable to delay publication of the facts obtained in the hope that topographic maps of northwestern California will be available in the near future.

The Russian River is one of the major streams of the California Coast Ranges north of San Francisco (map, plate 1), and has many interesting physiographic peculiarities, but the one which characterizes it to the eye of the ordinary observer may

be stated in a single sentence. After following for fifty miles its regular southeasterly course to Santa Rosa Valley, it turns away from this flat and uninterrupted alluvial plain which opens directly to San Francisco Bay, and flows westward to the ocean through twenty miles of rugged cañon, winding through a highland that varies from eight hundred to twelve hundred feet in elevation.

Hypotheses Already on Record

Such an abrupt change of course under these conditions naturally suggests one of two primary hypotheses: either capture of the upper portion by the headward erosion of some short coast stream thenceforth technically termed a pirate stream, or, secondly, that the transverse portion of the river from the open valley through the highland was antecedent to, and persisted through, the uplift which made the highland. Both of these hypotheses are already on record. Lawson in a reconnaissance paper in 1894 commented on the stream as follows:

> Associated with the subsidence which flooded the Bay of San Francisco there were probably other deformations of the crust which seem to have had an important influence on the drainage. The most notable instance of this kind is the shifting of the divides of the hydrographic basin of the Russian River. This stream once clearly flowed down through Petaluma Valley to the main drainage outlet at the Golden Gate. A low divide in the middle of the old valley now causes the drainage to flow westward at right angles to its former southerly course, and seek the coast by the present transverse route. The change in the drainage may be due to stream capture or to crustal warping. The latter is most probably the cause; but the problem has not yet been studied sufficiently.[1]

Quite recently Lawson has again incidentally referred to the subject.

> On account of the rather immature character of the transverse outlet of Russian River, it has been suggested that it is of later date than Russian River and represents a small stream which has cut it way back from the coast and captured the waters of the river, which formerly went to the Bay of San Francisco, the capture being facilitated by the deformation of the region. The offsetting consideration to this objection, based on the less mature aspect of this part of the valley, is that it

[1] The Geomorphogeny of the Coast of Northern California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, no. 8, p. 269 (1894).

traverses much harder rocks than are found in the wider valley above. In a word, the view that the lower transverse stretch of Russian River may be the remnant of an original consequent stream, from which by subsequent development has been evolved the longitudinal Russian River Valley, has not yet been satisfactorily negatived.[2]

Fairbanks has recently referred briefly to the lower river as follows:

> The Russian River is separated by an almost imperceptible divide from San Francisco Bay, but leaves this unobstructed course and turns at right angles and cuts a canyon through the mountains to the ocean. The only explanation possible is that when the river assumed its present course the surface features must have been very different from those of the present. The course which now seems so anomalous was then the most natural one.[3]

POSSIBILITY OF SUPERPOSITION

Other theories for the derivation of the course of the lower river are at once forced upon the attention of the student by a more extended examination of its valley. These will now be briefly outlined. It is possible that in a former period the region which is now the basin of Russian River, after a considerable period of stream dissection, was depressed and received a material load of sediment. With subsequent elevation a new drainage system developed upon the surface of the recently deposited terrane, its direction of flow being determined by the initial slopes of the uplift unaffected by the buried topography. Since then erosion has largely removed the recent soft deposits, leaving the present Russian River in much of its course superimposed unconformably upon the resurrected topography. Parts of the river may have chanced to return to the original channel, making what McGee has called "a resurrected river."

In technical phrase, then, we have four hypotheses for the peculiar course of the lower Russian River; viz., it may be a pirate, an antecedent, a superimposed or a resurrected stream. These hypotheses will be examined in the light of the field evidence to be discussed later.

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[2] The California Earthquake of April 18, 1906. Report of the State Earthquake Investigation Commission (Carnegie Institution of Washington, 1908), p. 20.

[3] Fairbanks, The Geography of California (San Francisco, Whitaker & Ray Wiggin Co., 1912), p. 94.

The citing in these introductory remarks of the references already made to the abrupt change in the course of the lower river and the enumeration above of possible explanations has a tendency to create the impression that this is the only peculiarity deserving attention. There are, however, many other instances where Russian River departs from the simplicity of the uneventful stream that simply flows down hill by the nearest route to the sea. Some of these unusual characteristics throw light on the life history of the river as a whole, while others are so involved in the general geomorphic history of the Coast Ranges that at this time they can be mentioned merely and left for study in connection with correlated facts in other localities.

General Features of the Coast Ranges and Their Relation to the Russian River

The Coast Ranges, in accordance with growing usage, are defined as extending northward from central Santa Barbara County, about Lat. 34° 45′, to South Fork Mountain, a linear ridge which, beginning in the vicinity of North Yallo Bally Mountain west of the northern end of the Sacramento Valley extends northwesterly, reaching the coast just south of the mouth of the Klamath River in approximately Lat. 41° 30′. The width of the province varies from forty to seventy miles. Topographically it is composed of a series of roughly parallel ridges and valleys which have on the average a trend somewhat oblique to the coast line and also to the western boundary of the great interior valley of California.

That the geomorphic history of the northern Coast Ranges is long and complicated, is well established, but there has not been sufficient study of the physiography of the region to furnish the details of this history. A few broad statements will present the commonly accepted essentials that bear on the physiographic history of Russian River so far as that history can at present be written. It is to be noted, however, that the writers quoted below on the geological history of the various portions of the Coast Province do not agree upon all details nor upon the exact sequence of events.

Peneplanation

It is generally agreed that in geologically recent times there developed over much of the Coast Range Province a more or less complete peneplain which extended also over the Klamath region.[4] During the latter part of this peneplanation period local folding occurred, with heavy deposits in the depressions. These deposits were later considerably folded and eroded, the peneplain persisting over extensive areas. Probably near the beginning of Quaternary time an elevation occurred which is supposed by some to have carried the land higher than its present position. This period of renewed erosion was followed by a depression, the recovery from which was by an intermittent uplift with the intervening periods of stability long enough for the carving of the series of terraces so prominent in portions of the coast and along many of the streams. The present coast line bears evidence of minor local depressions and elevations which probably were characteristic also of each of the former strands represented by the ocean terraces. The limited surveys thus far made show a lack of exact parallelism in the successive strands, favoring the idea of local irregularities with each uplift. This is of course to be expected, the surprising fact being the approximate uniformity in height of the major ocean terraces along the entire California Coast.

Stream Development

The uplift following the partial or complete peneplanation of much of the Coast Ranges inaugurated a new geographic cycle. Theoretical consideration of streams at the end of the preceding long erosion period and a few of the possible results of the succeeding uplift and folding may be helpful in considering the drainage pattern of the Coast Ranges today. In the middle age of the erosion cycle producing the peneplanation, streams would have become thoroughly adjusted to the underlying structure, i.e., resistant strata would stand out as ridges, and streams would have developed channels in the softer beds. Drainage

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[4] Branner, Newsom and Arnold, Folio 163, U. S. G. S., pp. 10–11. Diller, Bull. 196, U. S. G. S., pp. 15, 45, and 60. Fairbanks, Folio 101, U. S. G. S., pp. 11–12. Lawson, Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, p. 242.

thus thoroughly adjusted to underlying structure is technically termed "subsequent" drainage and in the area under discussion the streams would have acquired the NW-SE trend characteristic of the coast province today.

As the topography passed from maturity to extreme old age in those regions where peneplanation was complete, the streams would finally become independent of structure, weathering having removed the ridges, and underlying rocks having been covered with deposits or with deep residual soil. On this plain streams would meander indifferently, shifting to avoid slight obstacles.

We have thus to consider two classes of streams very distinct in their extreme types, and affected in markedly different ways by the succeeding elevation of the land. Where erosion and deposition had developed a featureless plain, rapid uplift and tilting would easily originate a new set of streams, their channels consequent upon the new slopes of the land surface. After a relatively short period of erosion, all signs of the former drainage channels would be obliterated. In the uplands of the old cycle, adjacent to the areas of complete peneplanation, streams would still be in the middle age stage, thoroughly adjusted to underlying structure and well entrenched. For such streams a very great change of slope would be necessary to throw the drainage into new channels and when the change was made, remnants of former valleys would frequently be left as a record of the changes. With this class of streams, various possibilities as to the effect of uplift are to be considered, a few of which may be formally stated.

Uplift of a block without tilting would give greater velocity to streams near the ocean and falls and rapids would develop and progressively work up stream. Tilting of a block in the direction of flow would rejuvenate the stream, increasing the velocity throughout, and tending to a deepening of the valley along its entire extent. Tilting against the flow of streams would slacken the current and result in deposit and aggradation, or if the tilting were sufficient, it might even cause a reversal of flow.

Slow upwarping of a belt across a stream might result in the downcutting of the stream through the anticline at a rate equal

to the rate of uplift. This would, of course, produce a stream recognizable as "antecedent" to the uplifted ridge. A more rapid upwarping would break the stream in two—rejuvenating the lower and reversing the upper portion.

As these various changes and their many possible modifications progressed, the resulting major streams might become extremely composite. Bearing these suggested possibilities in mind, the investigation of any coast stream of today begins with the question as to how far its course is consequent upon the last great uplift and with an examination into the origin of the portions having a more complex history.

The Natural Subdivisions of the River

With this brief consideration of the regional environment of the Russian River, the physiographic features of the stream will now be discussed. In studying the characteristics of its hydrographic basin from the standpoint of physiography, there are three natural subdivisions which may conveniently be used as units: the upper river from the source to the sudden termination of the gorge just above Cloverdale; the middle river from Cloverdale to the mouth of Mark West Creek, on the west side of the Santa Rosa Valley; and third, the lower river, comprising the cañon leading westward from the Santa Rosa Valley to the sea. Arbitrarily chosen limits to subdivisions in nature fail to meet all of the actual facts, but there exist three parts to the river with distinct problems and the points of subdivision given above come in zones of transition which really separate the natural divisions.

THE UPPER RIVER

The boundaries of the basin of the Upper River form three sides of a rough parallelogram, the lines being quite regular compared to water-partings in general. On the east, the St. Helena Range, with a crest-line rising to an elevation of from 3000 to 4000 feet, separates the river from the drainage of Clear Lake, whose outlet, Cache Creek, flows southeasterly into the Sacramento Valley. On the north an irregular transverse ridge from 1800 to 3500 feet in height makes the water-parting between the Russian and the Eel rivers which flow in diametrically

opposite directions from this divide. To the westward the water-parting parallels St. Helena Range, but is somewhat lower in elevation, seldom exceeding 3000 feet in height. This western ridge has no accepted name, but might appropriately receive the designation Mendocino Range, a term sometimes used and very properly applied to the highest and most regular water-parting in Mendocino County.

Mendocino Plateau

From Mendocino Range to the ocean lies a thoroughly dissected plateau on which the streams flow directly toward the sea. If the drainage map, plate 1, be examined, this area stands out prominently as the only region of any extent which has a normal consequent drainage to the ocean in distinction from the typical NW-SE drainage characterizing the Coast Province as a whole. Lawson noted this group of streams in his northward reconnaissance trip and briefly described their consequent character.[5]

This plateau area to the west is closely related to the Upper River in geomorphic history. If we obliterate from the map (plate 1) the main trunk of the Upper River, the tributaries *from both sides of the valley* fall into line as linear extensions of the headwaters of the drainage of the Mendocino plateau.

That tributaries from the opposite sides of the river *do* thus have a common direction is possible because the tributaries on the east from Cloverdale to Ukiah are abnormal in their position relative to the trunk stream. These eastern branches of Upper Russian River have a definite *northwesterly* direction instead of southwesterly as should be the case had they developed normally as tributaries of a southerly flowing river. This northwest direction of the eastern tributaries is an abnormality demanding explanation. The theory that the Russian River once flowed in the opposite direction offers no satisfactory solution, for in that case the tributaries on the west would have flowed in an equally incongruous direction.

The fact of the tributaries on the two sides of the Upper River of today being thus diametrically opposed in direction of flow, and the further fact that the linear direction of their

[5] Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, p. 252.

combined valleys agrees with the direction of the valleys of the Mendocino Plateau, find their best explanation in the hypothesis that these tributaries have inherited valleys which originally developed on that plateau at a time when it extended eastward to the foot of the St. Helena Range.

This hypothesis is strengthened by consideration of the relative direction of the streams in different parts of the area. The linear direction of the opposing tributaries of the Upper River varies from approximately N 50° W near Cloverdale to nearly due west at the upper end of the valley and the direction of the streams of Mendocino Plateau becomes more westerly in the same degree in passing northward.

The interpretation above of the relation of the Upper River to streams of Mendocino Plateau is in entire harmony with the commonly accepted theory that the Upper River is a subsequent tributary of the main stream, a tributary which has developed northwestward by headward erosion along a line of structural weakness. In its headward extension it has successively tapped the various coast streams, capturing the eastern headwaters and reversing a portion of the western channel of each. The large number of coast streams beheaded and the regularity of the water-parting to the west would suggest that the process has been materially assisted by diastrophic changes in the Mendocino Plateau. It is probable that the crest line of the range is either the edge of a fault block or the axis of an anticline.

Without some such control it is also difficult to understand how the successively beheaded coast streams could have their new divides pushed seaward to approximately the same line in every instance as is indicated by the map, which shows that the southern coast streams, though first beheaded, have lost rather less territory than have the northern and latest affected streams.

In connection with this idea that structural conditions have controlled the regularity of the western divide of the Upper River basin, it is worth while to call attention to the fact that the drainage map shows near the summit of the Mendocino Range a marked tendency for the secondary tributaries to take a direction parallel to the main crest. This is particularly noticeable in the streams of the Rusian River side of the divide, where many

of the headwater gorges approximate parallelism to the axis of the range for several miles, suggesting the influence of a secondary line of diastrophic or stratigraphic weakness.

The Beheading of Navarro River

Field evidence that the coast streams of the plateau did formerly head against the St. Helena Range—the eastern boundary of the present basin of the Upper Russian River, should exist in remnants of old stream valleys in the gaps of Mendocino Range. Lack of time and the difficulty of thoroughly exploring a rough and unmapped territory have prevented an exhaustive search for such abandoned channels. Some five years ago before this idea of the beheading of the coast streams by the Russian River had become a conscious hypothesis, the writer in crossing Mendocino Range was impressed by the fact that the pass at the head of Navarro River has a flat alluvial floor of considerable extent. Yorkville Pass—to name it from a nearby village—lies to the northwest of Cloverdale and is directly in line with Big Sulphur Creek, one of the northwest flowing tributaries on the eastern side of the Russian River. Recently Yorkville Pass was revisited and definite indications of the former southeastward extension of Navarro River were found.

The elevation of the pass is 1030 feet, corrected aneroid. The view of the floor of the pass in figure 1, plate 2, is taken looking toward the southeast. Every student of physiographic forms will be struck by the topographic unconformity of the broad alluvial floor and the gentle hill slopes when considered in relation to their location on a main divide that is reached by ascending narrow and youthful valleys. To the northward the mountains attain a height of 3000 feet within two miles and the elevation to the southward appears fully as great. That is, Yorkville Pass is a low, broad cut in the crest of the range. The alluvial floor of the pass is cut off rather abruptly on the east by the headwater gorge of a tributary of Russian River. A climb of some forty feet up the south slope of the pass to get above the trees gives the view in figure 2, plate 2, which shows the gentle curves of the extension of old Navarro River. Although not visible in the picture, the drainage channel of the inverted flow to the Russian

River is sunk below the floor of the old valley. The main tributaries are hidden by the trees on the right. The open, grassy stretches on the left, formerly the slopes of the old valley, are now the tops of the transverse ridges between the minor branches. The old valley may be traced southeastward for several miles, the same section of an open valley with subdued mature topography appearing on the tops of the minor ridges to the eastward at elevations from fifty to one hundred feet higher than Yorkville Pass itself. As the Russian River is approached remnants of the old valley are naturally lacking because of the greater general erosion consequent upon the tributaries of the present stream cutting down to the rather low base level determined by the main channel.

The opposing tributary on the east of the river is Big Sulphur Creek, which empties into the river through the youthful gorge shown in plate 3, figure 1.

That this tributary is probably the beheaded portion of the old Navarro River is indicated by several physiographic conditions. First among these are its inharmonious relation to Russian River and its northwesterly direction of flow in linear extension of Navarro River and of the old valley found at Yorkville Pass and vicinity. The youthfulness of the lower portion of Big Sulphur Creek is also explained by the theory of capture. The grade of Navarro River would carry it far above the Russian River and capture must have been followed by rapid deepening of the channel of the new tributary. It is interesting to note in this connection that on going up Big Sulphur Creek the gorge, after four or five miles, changes to a valley of gentler and more mature slopes. Still further up stream the channel is deeply incised in the slopes of St. Helena Range. These characteristics are in entire harmony with the theory of capture, but no study has been made of the more mature middle portion of Big Sulphur Creek to see if there may be other determining factors.

The field evidence of the beheading of Navarro River affords satisfactory support to the theory of former eastward extension of the plateau streams, but it is not an ideally simple case in that the old channel from the crest of the range to Russian River is not occupied by a single reversed stream. Inspection

of the map will show that the channel has been cut in two by the headward growth of Dry Creek, the tributary of Russian River already mentioned as paralleling the main stream in direction, which will be discussed more fully in the section on the Middle River.

The crest-line of the Mendocino Range was examined at but one other point for evidence of abandoned channels. In this case the North Fork of the Navarro opposes on the divide a creek emptying into Russian River just north of Ukiah. The lowest point of the divide was found to be over 1800 feet in elevation. The summit of the range is thoroughly dissected in this vicinity, and no signs of former valleys exist. No field evidence was found contradictory to the theory that the coast stream had been beheaded, but the only evidence in its favor in this instance was the common direction of the opposing streams. However, the topography around Yorkville Pass, together with the map evidence of seven or eight northwest-flowing tributaries on the east of the Russian River which fall in line with the western tributaries and also with coast streams, fully justifies the advancement of the general theory of capture here outlined.

Easternmost Tributary

In a former publication it was shown that one tributary of the Russian River recently headed to the eastward of St. Helena Range.[6] In this instance Scott Creek, a present tributary of Clear Lake, draining an area of from eighty to one hundred miles, was proved to have been formerly the upper portion of Cold Creek, a branch of the east fork of Russian River. A large landslide occurring probably hundreds of years ago but still plainly evident, cut off this stream and diverted it to Clear Lake, making it part of the Sacramento drainage.

The field evidence that Scott Creek was thus cut off and diverted to Clear Lake is, in the opinion of the writer, incontrovertible. Whether the present channel carrying the waters of Scott Creek to Clear Lake was made subsequent to the landslide as stated by the writer in the article quoted, may, perhaps, be

[6] Holway, R. S., Physiographic Changes Bearing on Faunal Relationships, Science, n.s., vol. 26, p. 382; Sept. 20. 1907.

debatable. Fairbanks[7] has recently asserted, in a general description of the region, that Cold Creek received the drainage of Clear Lake prior to the landslide, but without giving any field evidence.

The stream valley in question seems too narrow for the outlet of Clear Lake hydrographic basin, considering its average rainfall. It is of course possible that the lake had another outlet at the same time and that but part of the outflow was into Cold Creek. Snyder states[8] that the biological evidence from the study of the fauna of the Russian and Sacramento rivers indicates that a transfer may have been made from the Sacramento to the Russian River rather than the reverse, as the transfer of a tributary from the Russian to the Sacramento system would have no effect on the faunal relationships of the two basins because of the fact that the Sacramento contains not only all the fluvial species known from the Russian River, but also others not represented. The diastrophic history of Clear Lake basin is not worked out in detail, but recent deposits[9] and terraces suggest the possibility that tilting may have caused the outlet to be sometimes to the east and sometimes to the west. Further field work covering the lake basin is necessary before final conclusions are drawn. In its physiographic relations Clear Lake belongs to the long list of interesting and unsolved problems which are found in the Coast Ranges.

So far as the history of Russian River is concerned, until the whole question of the outlets of Clear Lake is studied in the field, it can only be stated that a tributary of Russian River has recently been diverted to Clear Lake and that there is strong probability that the lake has at some time flowed into the river. That no tributary of Russian River other than Cold Creek ever headed to the east of St. Helèna Range seems very probable from the general topography. The range is the backbone of this portion of the Coast Province, and Cold Creek is the only low gap through it in the forty miles that it parallels Russian River.

[7] Fairbanks, H. W., The Geography of California, p. 96.

[8] The Fauna of Russian River, California, Science, n.s., vol. 27, p. 269 (Feb., 1908).

[9] Becker, Geo. F., Monograph 13, U. S. G. S., ch. 6.

The Gravel Deposits

San Benito River, which rises nearly one hundred and fifty miles to the southward of San Francisco, flows northwesterly in the southerly portion of the same geomorphic valley which in its northerly part is occupied by Russian River. The correspondence between these two streams in regard to their relative position in the valley of the Bay of San Francisco and in their cutting gorges westward to the ocean will be treated more fully elsewhere. Other similiarities in history also exist. Lawson, in summing up evidence of the general uplift of the coast from the Golden Gate to San Diego, refers to the gravel deposits of the Santa Clara-San Benito Valley.

> This valley is occupied by a trenched and terraced Pliocene delta. This fact is not so apparent at the middle or Santa Clara portion of the valley as it is at its lower and upper portions. The lower portion is occupied by the Merced series, which has already been described. The upper portion from Pajaro Cañon southeastward, reveals the delta in a great volume of approximately horizontal gravels. . . . These gravels are exposed on the San Benito, the Tres Pinos, and Los Meritos in a series of very remarkable cliffs often 1000 feet high. . . . In these facts we have all the evidence that could be desired for the conclusive demonstration of (1) the depression of the coast in Pliocene time during the accumulation of the gravels, (2) the great volume of the Pliocene strata, certainly not less than 1200 feet, (3) the correlation of the San Benito gravels with the Merced series at the lower end of the same valley, (4) the uplift of the valley with its load of gravel in post-Pliocene time to an extent not less than the measure of the altitude of the plateau near Tres Pinos.[10]

The analogy between the Russian and San Benito rivers is so clear that the quotations above and much of the accompanying description could be applied almost verbatim to the Russian River by the transposition of localities and figures. The deposits of gravel in the Santa Rosa Valley and in the Middle River, to be described later, correspond to the deposits of Santa Clara Valley and vicinity in the Southern River.

In the upper Russian River, terraced gravel deposits appear at Hopland, where the local widening of the cañon is probably due to their rapid removal by erosion. The valley floor near

[10] Post-Pliocene Diastrophism of the Coast of Southern California, Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, no. 4, pp. 152–153 (1893).

Ukiah is another local enlargement of the Upper River Valley and has well marked terraces, making the "bench" land of the farmers. On the east of Ukiah the deposit rises from three hundred to four hundred feet above the river, standing in sheer bluffs when undercut by the stream (plate 3, fig. 2). About three miles to the northward this gravel deposit is cut by the east fork of the Russian River, and here it is planed off, making a very definite terrace about 240 feet above the river and 850 above sea-level (plate 4, fig. 1). Northward across East Fork the gravel extends as a prominent ridge just east of the main river. At Calpella it is crossed by a wagon road, and good exposures of gravel appear even to the highest point, about 950 feet above sea-level.

Extensive gravel deposits are found to the westward of Calpella, and the flat at Laughlin, 872 feet railroad level, seems to be the extension of the gravel terrace at the forks of the river. No attempt was made to map the extent of the gravel, a task requiring time, outcrops and river terraces being masked by the covering of forests. Gravel of the same appearance is found at the mouth of the tunnel north of Laughlin at about 1340 feet. The width of the valley of the East Fork narrows abruptly about two miles east of Calpella, where the gravel deposit ceases, the narrow cañon immediately upstream being cut in hard rock. Above this youthful gorge is found Potter Valley, interesting as an example of the intermontane valleys that occur rather frequently in the northern Coast Ranges (plate 4, fig. 2). This valley is the gathering place of the headwaters of the East Fork of the Russian River. Its flat alluvial floor is some eight to ten miles long by four or five in width, and lies at an elevation of 1100 feet.

In places the plane of the valley floor changes abruptly to the slope of the inclosing hills, indicating a filled water surface. The lack of this feature upon all sides of the valley may indicate that where it occurs the cause is local tilting and ponding of drainage, and that the evolution of Potter Valley as a whole is not to be fully accounted for by the theory of a filled lake basin. The origin of these intermontane valleys in this region has not been worked out. Diller refers to similar depressions to the northward

in the Eel River Basin and suggests that "their development may indicate the presence of a large mass of soft Miocene rocks."[11]

Removal of easily eroded deposits apparently accounts for the existence of a valley that has just been added to the drainage of the Upper River by what may be termed "assisted piracy" in technical physiographic language. The headward erosion which shifted divides in this case was made by the tunnel which a water power company drove through the northern wall of Potter Valley and which has captured the South Fork of Eel River. In June, 1912, the entire flow of this stream, which drains the northern part of Lake County, was being transferred to the Russian River. In the captured basin the gravel deposits are quite extensive. A valley some five miles in length, locally known as Gravelly Valley, has been eroded to a base level which is apparently determined by resistant rocks in the gorge to the westward of Hullville, through which the South Fork of Eel River runs until it is diverted by the dam and tunnel of the water power company. The floor of Gravelly Valley is gravel, and large masses of gravel are found on some of the slopes. Through the floor of the upper part of the valley occasionally project masses of the harder rock of the region—apparently the tops of the residual resistant hills of a former erosion cycle.

Consideration of the gravel deposits of the Upper Russian River suggests the possibility that its valley may have in part at least existed prior to the present cycle and that the erosion of the gravels is resurrecting portions of its old valley. The narrow and more youthful parts are, according to this view, the connecting gorges developed where the channel during the removal of the gravels was let down on the more resistant rocks of the older topography.

In connection with this suggestion it should be noted that below the widening known as Ukiah Valley the Russian River flows in a gorge which again broadens about eight miles to the southward. This locality has not been studied by the writer, but as seen from the train there are strong indications that the river

[11] Diller, The Topographic Development of the Klamath Mountains, Bull. 196, U. S. G. S., p. 55.

here has been superimposed on the older topography to the east of a former valley, as the alluvial floor of the local broadening seems to be separated from the present channel by a rocky ridge.

Down stream, the next expansion of a gorge into a flat-bottom valley occurs at Hopland, and has already been mentioned in connection with the terraces found in the upper valley. From Hopland to the termination of the Upper River near Cloverdale, its gorge-like character is maintained with no gravel deposits noted in the rather hasty survey yet made.

The possibility that the present Upper River is largely the resurrection of a subsequent stream developed prior to the deposition of the gravels is not advocated, but merely recorded as a hypothesis deserving attention when contour maps are available and the areal geology mapped, making possible the determination of the existence of an Upper Russian River in a previous geographic cycle.

Subsequent Character of the Upper River

With the present lack of definite information as to the geology of this region, no detailed hypothesis is advanced for the original control of the Upper River in its northwestward extension. That the line of weakness is a fault line is, of course, suggested by its straightness. The diametrically opposite direction of flow of the Eel and Russian rivers has already been mentioned. The cañons of the upper courses of the two rivers for a distance of eighty miles within Mendocino County very closely approximate a straight line. The bearing of this line is about N 15° W. The bearing of these lines becomes interesting in connection with Lawson's recent recognition of two systems of fault lines in his discussion of the trend of the coast line to the westward. The trend of the Upper Russian River closely approaches and may be genetically connected with the more meridional system described above.

If along the shore line at the base of this abrupt slope we draw straight lines which are tangent to the headlands, or chords to the minor embayments of the coast, these lines fall into fairly constant orientations and clearly bring out the fact that the shore line has in reality a zig-zag course, due apparently to the alternate control of two systems

of structural lines, one of which is between N 37° W and N 40° W, and the other between N 10° W and N 15° W, thus intersecting at an angle of about 26°.[12]

This study of the Upper Russian River has, as was expected, substantiated the theory suggested to all students by a mere study of the map, namely, that it is subsequent in character, owing the straightness of its course to the control of a line of structural weakness. The history of the headward erosion of the stream in its development has been complicated by diastrophic changes in the Mendocino Plateau and by the presence of the extensive gravel beds deposited during the depression at the close of the preceding cycle of erosion. The tributaries of the Upper River from Cloverdale to Ukiah are held to be the captured headwaters of the present streams of the Mendocino Plateau.

THE MIDDLE RIVER

The Upper Russian River flows in a cañon which widens locally into small flat-bottomed valleys, noticeably so at Ukiah and at Hopland; the Middle River may be described as occupying an open alluvial valley which narrows midway to a gorge. The lower ten miles of the Upper River has no valley floor other than the narrow gravelly or rocky flood-plain covered by the winter floods. There is no gradual transition from this gorge (fig. 1, plate 5) to the wide alluvial floor of the Middle River shown in the lower figure of the same plate. At Preston, two miles above Cloverdale, the gorge abruptly stops and the open valley as abruptly begins with an actual width of nearly a mile, and an apparent width of twice that extent, due to the well-graded floor of a tributary valley which enters here from the west. The cause of this sudden change in the character of the main river valley is probably to be found in the movement of fault blocks. From the hills north of Cloverdale a view of the mouth of the gorge suggests a cross fault with the relative downthrow on the south. The period in which displacement along this fault took place must be remote, for a closer examination reveals no clearly defined

[12] Report of the State Earthquake Commission, p. 14.

fault scarp. Another fault with its strike along the course of the river is suggested by the rather steep and regular wall of the valley east of Cloverdale. This scarp is continuous with the eastern wall of the gorge above Preston, which for several miles northward shows the scars and hummocks of landslides, some of them recent. Downthrow on the west and southwest of these two fault lines is indicated by the aggraded floor of the valley below Preston. The wide flood plain seen at Cloverdale extends for fully fifteen miles to the southeast, a width of over three miles being reached just below Lytton. Extensive deposits of gravel correlated with the gravels of the Upper River are found on the west side of the valley and the history of their deposition is probably connected with movement of the fault-blocks mentioned above. Distinct terraces are found on both sides of the valley. Below Cloverdale, on the eastern side, low terraces, forty to sixty feet above the flood-plain, are in many places cut in the rather extensive serpentine belt found here. On the western side the terraces are higher and wider, especially in the gravel deposits. The wagon road for some distance runs on the top of a rather broad terrace at an elevation of 360 feet, fully 150 feet above the river. Fragments of higher terraces were seen but not examined.

Cañon Through Fitch Mountain

On approaching Healdsburg, peculiarities appear which more clearly differentiate the middle from the upper portion of the river. At Lytton the railroad leaves the river valley and finds an easy grade up a slight slope rising to but thirty feet above the highest flood water of the river, and then descending to the river bank again at Healdsburg only four miles to the south. To reach the same point the river, however, takes from Lytton an indirect and difficult course of about fifteen miles, continuing southeastward for five or six miles and then abruptly turning to the northwest and flowing through the high and rugged Fitch Mountain group of hills in an irregular "S" shaped cañon. This long and meandering course of the river through high hills rather than through the open and direct route followed by the railroad is utterly out of harmony with the present topography

and is evidently an inheritance from a past geographic cycle. A minor incongruity occurring in Alexander Valley bears illuminating testimony as to the events connecting the river of today with this past cycle when the course of the stream was normal to the conditions then existing.

Alexander Valley

Southeasterly from Lytton station, just south of the river bridge, a buttress of the lower ridges of Fitch Mountain extends out nearly a half mile into the alluvial plain which here bears the local name of Alexander Valley. Although to the eastward of this projecting obstacle the valley floor sweeps broadly around to the river below, the stream has cut a gorge directly through this rocky spur (plate 6). Such an unconformable relation of the stream to the topography can be explained only by the supposition that after the elevation following the deposition of the gravels, the river flowed indifferently over a plain, regardless of buried hills, and that later in cutting down its channel the ridge was discovered. Thereafter the stream erosion even in the rock of the ridge evidently deepened the channel faster than general erosion removed the recent deposits in the broad valley. Finally, however, the downward cutting in the river channel practically ceased because the level had been lowered to its present position of approximate final grade. Since then the gradual lowering of the valley floor by the general process of denudation has left the incongruity of the river cutting off the point of the projecting rocky buttress rather than swinging around it in the open plain. This detailed history of the past is the only reasonable explanation to be found and clearly puts this portion of the stream into the class of superimposed drainage.

The entire anomalous course of the river in its meandering cañon through Fitch Mountain instead of following the more direct way may undoubtedly be similarly explained. Fitch Mountain is over 900 feet in elevation and from the north appears to be the prolongation of the highland east of Santa Rosa Valley. The mountain must have been covered with sedimentary deposits nearly to the summit to make a plain upon which the river could acquire its present meandering course.

The Maacama Slide

The notable Maacama Slide, which occurred during the earthquake of 1906, revealed an interesting bit of evidence of the existence of a former drainage level higher than that at present, yet probably at a period when the superimposed drainage had been let down until the river was well notched into the Fitch Mountain group. This landslide occurred about four miles southeast of the rocky spur mentioned above and about half a mile from the river. During the few seconds of the actual quaking a section 600 feet wide of the entire top of a narrow ridge slid northward into the flat of Maacama Creek. In the wall of the cut thus exposed, at the very top of the present ridge, a section of an old stream bed filled with gravel was revealed. The level of this channel, about 250 feet above the Russian River (and 400 feet above sea-level) is by no means to be taken as the full measure of the thickness of the deposit removed in the present cycle, as this small tributary may have been abandoned at a late stage in the denudation. It necessarily, however, fixes a minimum for the erosion at this point. Refilling the valley to this level would entirely cover the hills south of Lytton station and the rocky spur cut off by the river in Alexander Valley.

Evidence that the hills south of Lytton station must formerly have had a higher altitude is also furnished by the fact that river terraces exist in the cañon through Fitch Mountain at an elevation from forty to fifty feet higher than the present railroad pass from Lytton to Healdsburg. The presence of gravels on the hill tops in the vicinity of the railroad indicates that this former greater altitude of the hills was probably due to a sedimentary covering, an idea which is in harmony with the theory advanced that the general course of the Middle River is due to superposition.

Course South of Healdsburg

After the river emerges from Fitch Mountain Cañon its course for ten miles runs through the open Santa Rosa Valley. The railroad level at the station in Healdsburg is ninety-nine feet, and the river during the summer season is fully twenty feet lower. The stream is now eroding laterally in the main, and is swing-

ing rather freely within its flood plain. Near the Calhoun Ranch, south of Healdsburg, it is reported that in twenty-five years the channel moved over a mile to the west and in the next twenty years returned to within one hundred yards of its former position. In the five years following it has again moved westward more than half way on its return swing. A rather permanent change of course is topographically recorded a mile and a half southeast of Healdsburg. Here on the east of the railroad track may be seen the curving belt of somewhat marshy land which lies on the north of the undercut bluff of a former bend of the river. The rest of the old ox-bow is completely obliterated by recent deposits.

The question of greatest interest in this portion of the river is the genetic relation of its course to the Santa Rosa Valley. So far as known to the writer no reference has yet been made to the topographic relations really existing. The axis of the valley, it is well known, has from Healdsburg to tide water at Petaluma the southeasterly trend so characteristic of the main features of the Coast Ranges. The course of the Russian River shows no sign of being affected by this greater depression. The river crosses the head of the Santa Rosa Valley at Healdsburg (plate 7, fig. 1) and thence southward to its junction with Mark West Creek runs in a smaller valley which it has incised in the western slope of the main valley. This smaller valley extends from near Healdsburg due south about eight miles to the mouth of Mark West Creek, a tributary entering from the east which is important in the later consideration of the Lower River. At the junction of the streams, the river is about sixty feet above the sea, and the level top of the terraced point between the streams 240 feet, while the hills to the rear rise to at least 300 feet.

Southward across Mark West Creek the hills rise to nearly 500 feet, while the floor of the Santa Rosa Valley immediately eastward is under 100 feet in elevation. From the hills to the southward of Mark West Creek a good view is obtained of the incision of the channel of the Russian River in the west slope of the Santa Rosa Valley. Plate 7, figure 2, is the reproduction of a photograph taken in the haze of midsummer but still definitely showing the main facts.

Santa Rosa Valley is about forty miles in length, extending from San Pablo Bay to Healdsburg, the greatest width of its flat alluvial floor being about ten miles. According to Osmont,[13] the valley is synclinal in structure and owes its level alluvial plain to widening by subsequent erosion. The valley floor has been eroded in the gently folded Merced series, which, he estimates, have a thickness of over 2000 feet. In a section just north of the mouth of Mark West Creek he shows the Russian River as resting on the Franciscan rocks with the Merced beds "along the east bank . . . dipping to the east and disappearing under the valley alluvium."[14]

In Osmont's opinion, during the subsidence resulting in the deposition of the Merced series, the sea encroached on the land from the west to form marine deposits, an opinion supported by his finding probable Merced strata in the foothills southwest of the mouth of Mark West Creek. The presumption is, that the Merced series mantled much of the highland to the west.

Under these general conditions the explanation of the fact that the bed of Russian River is in a cut in the western slope of the valley rather than in the lowland of the axis must rest in the existence of the stream prior to the synclinal folding that made Santa Rosa Valley and in the further fact that it was able to erode with sufficient rapidity to keep its course during the uplift of the seaward side of the syncline. Whether in every part of its course south of Healdsburg the river has been let down through the soft and friable Merced series upon the harder rocks beneath is not easily determinable. As a whole, however, the Middle River, with its meanders through Fitch Mountain and its shallow gorge cut in the west slope of Santa Rosa Valley, is undoubtedly to be explained as superimposed upon the present topography, by downward erosion from an old surface through relatively recent deposits.

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[13] Osmont, V. C., Geological Section of the Coast Ranges North of the Bay of San Francisco, Univ. Calif. Publ. Bull. Dept. Geol., vol. 4, pp. 39–87.

[14] *Op. cit.*, pp. 67–68.

Improbability of Former Outlet Through Santa Rosa Valley

Although only the northern portion of Santa Rosa Valley is within the drainage basin of the Russian River, the oft-repeated assertion that the stream flowed through this valley to San Francisco Bay, makes it necessary to consider still further its physiographic conditions. Despite the fact just stated that more than half of its area is included in the drainage of Russian River Basin, structurally Santa Rosa Valley is to be considered a topographic unit. From any high viewpoint may be seen the seemingly absolutely flat valley floor, extending from Healdsburg forty miles to the southeast where it merges into the tidal flats near Petaluma. Throughout its extent it is definitely limited by apparently continuous ranges of hills on the northeast and on the southwest. Closer examination of the seemingly level valley floor reveals but slight differences in elevation along the axis of lowest level, provided the channel of the Russian River and its tributaries be omitted from consideration. At Healdsburg the northern bank of the Russian River is ninety-nine feet above the sea at the railway station. Going southeastward the elevation drops some twenty feet in crossing the broad flood plain of the river and then rises to about one hundred and twenty feet in the next four miles. In the succeeding eight miles it falls to about eighty feet. Disregarding the slight drop at Santa Rosa Creek and the lagoons opening into it, the valley floor then gradually rises along the axis, reaching its highest level of 113 feet at Cotati station about eight miles from tidewater at Petaluma. Cotati is on the indefinite water-parting separating the Russian River drainage from that of San Francisco Bay. Instead of a clear-cut ridge marking the water-parting there is the level alluvial field shown in plate 8, figure 1. The view should be studied in comparison with the lower figure of the same plate, which shows the valley which the Russian River has cut through the western highland to the ocean. Remembering that the alluvial field at Cotati rests on the easily eroded Merced series described by Osmont, a comparison of the two figures in plate 8 shows the extreme improbability that the Russian River ever could have flowed past Cotati to the bay and then subsequently

been captured by any stream working its way headward through the resistant rocks composing the highlands shown in the lower figure. Had the Russian River ever flowed to San Francisco Bay, the channel at Cotati in a comparatively short time would have been cut to approximate sea-level in the easily eroded sediments at that point. The upper end of the gorge of the Lower River near the mouth of Mark West Creek has a level of nearly sixty feet in the older and harder rocks, which again clearly negatives the idea of capture by a coast stream during the present geographic cycle.

Anticipating somewhat the discussion of the Lower River it may be stated here that old river levels are recorded on the slopes of the Russian River through the highlands at elevations approximating a level 300 feet above the Cotati plain. This also clearly disposes of any theory of capture of a river flowing by Cotati to San Francisco Bay unless the theory of capture be supplemented by the supposition of unusually sudden accompanying diastrophic changes. As already stated in the preceding description, the writer believes that the Middle River has, aside from the shifting of meanders, been approximately constant in position during the present geographic cycle and that drainage from the head of Santa Rosa Valley has never had an outlet to San Francisco Bay.

A closer examination of the valley floor near Cotati presents other evidence confirmatory of this view. As has been noted above, the floor of Santa Rosa Valley rises in passing southeastward along its axis toward Cotati and at that point begins to descend toward Petaluma at a steeper grade, reaching sea-level in eight miles as against nearly forty miles by the channel northward by way of the Russian River. These distances invite speculation as to shifting of divides in the future, but attention should first be called to an interesting fact in the topography of the vicinity. To the southwest of Cotati, the valley floor very definitely continues to rise toward San Francisco Bay, indicating that the headwaters of Petaluma Creek have been eating their way into a northward sloping valley floor which formerly extended still nearer to Petaluma.

The most natural interpretation of the topographic relations at Cotati is that instead of a former drainage of Santa Rosa Valley toward Petaluma there is now a stream contest going on in which Petaluma Creek has been and probably is now slowly capturing territory from the Russian River. The result of this contest it is not easy to foretell. The Russian River has resistant rocks to cut away but it has the cutting power of an active stream to accomplish the work. Were there any stream actually cutting through the alluvial field at Cotati the lowering of the divide would be very rapid. But the formation of headwater gullies in a flat, porous surface is naturally an extremely slow process and becomes still slower when the surface is a field under cultivation where human interests are opposed to the formation of gullies. The advantages are so well balanced that historic time will probably see but slight changes.

THE LOWER RIVER

As defined in this paper, the Lower River is the twenty miles of rugged cañon extending inland from the ocean through a well dissected highland of from 800 to 1200 feet elevation to the open Santa Rosa Valley, where the alluvial floor is less than 100 feet above the sea. This cañon is cut in old and generally resistant rocks and its many bends with their forested slopes make it extremely picturesque. To the student of earth forms it is attractive because of the number of striking illustrations which it furnishes of physiographic processes and their results. The topographic feature which possibly bears most directly on the problem of the past history of the river is the existence within the highland of meanders of as well-marked a type as those in the delta lands of the Sacramento.

Meanders

Meanders occurring in a dissected highland are commonly held to be an inheritance from a time when the region was a plain so low and smooth that the sluggish current was deflected by trifling obstacles. Large rivers also tend to meander when their courses are extended across flat delta lands. Slow uplift

of such areas quickens the current and entrenches the meanders in the rising ground, making difficult any subsequent straightening of the curves. In the case of the Lower Russian River, Osmont's supposition already quoted, that in the subsidence preceding the deposition of recent sediments, the sea transgressed from the west, involves the probability that at some stage the region of the present Lower and Middle River was a plain. practically at sea-level. Any stream from the interior extending across this area would be apt to have meanders, as is manifoldly illustrated along the extensive coastal plain of the Gulf of Mexico. The terraces already mentioned along the Russian River and along the California Coast, all vouch for the fact of recent uplift—recent in geological time but long distant in years, for since the uplift the meanders of the Lower River have been lowered by erosion and are again close to sea-level.

General atmospheric erosion has made but little impression on the tops of the hills and in places where tributaries have not developed, these hill tops show fragments of the plain which was uplifted from sea-level. Immediately northwest of Duncan Mills a hill top shows a considerable flat at 980 feet elevation, and projecting above its surface is a stack of hard rock similar to the stacks now standing on the ocean strand off the mouth of the river. Osmont[15] cites his finding surface rocks bored by sea mollusks at 800 feet elevation on the extensive flat tops of the hills along the coast immediately south of the river. Evidence more or less satisfactory then exists for all the stages of a past history necessary to derive the meanders of the Lower River from the meanders of a stream formerly near sea-level, meanders which have since been uplifted and then entrenched by erosion. Assuming for the present this history the actual conditions of today will be described in detail. The writer does not consider that all entrenched meanders must necessarily have been derived from meanders in an antecedent base-leveled plain. Moreover it is to be noted that the description following shows that the meanders of the Lower River have greatly changed their shape since the uplift. The essential point in the history of the river as here outlined is not the extent of the meanders of the former river

[15] Univ. Calif. Publ. Bull. Dept. Geol., vol. 4, p. 87.

but rather the fact that base-leveling had given the stream a direct course to the ocean.

An excellent illustration of the entrenched meanders of the Lower Russian River is seen in plate 8, figure 2. The photograph is taken from the top of Gabe's Rock, a residual peak about 900 feet high standing on the western border of the town of Guerneville. The view is toward the southwest and the river swings fully two miles to the left around Camp Vacation, returning behind the first ridge in the central foreground of the picture. This high level view does not give an idea of the present condition of the river itself. As has already been said the Lower River is now close to sea-level and downward corrasion has nearly ceased; hence the main strength of the current is spent in cutting laterally, especially on the outside of each bend. The upper view in plate 9 shows the extreme point of the bend just out of sight on the left in the general view in plate 8, figure 1. The undercut bluff on the outside and the sandy deposit on the inside of the bend are typical of the bends throughout the cañon. The extent of the flat on the inside of the bend varies with the local resistance. In plate 9, figure 2, is a view of the meander just above Guerneville looking eastward from the top of the cemetery hill. Here there is an extensive flat within the loop, showing the cutting since the river has been practically at base level. The dark spots in the field are the great stumps of redwood trees which formerly occupied the cañon. On the right is the "slip-off slope" of the down stream side of the spur projecting into the loop. On this slope river gravel is found recording various levels of the river. In referring to former levels of the river it must be remembered that it is quite probable that the Lower River has remained at approximate sea-level and that the terraces and river gravels really mark the amount of the successive uplifts of the land rather than the lowering of the river.

The Oxbow Cutoff at Guerneville

Wherever loops occur in a meandering river there is a tendency for erosion on the outside of the curves to cut away the intervening land in the narrowest part of the loop, making the oxbow cutoff, so familiar in the streams of flat alluvial

plains. In a river deeply entrenched in a plateau such instances of the cutting through of the loop are rare and when found are proportionately interesting. There has been but one such case in the Lower River, but that one instance furnishes a type example. It occurs in the highland midway from Santa Rosa Valley to the ocean at the town of Guerneville, which is situated on the north bank of the river. From the northwestern edge of town Lone Hill rises to a height of 230 feet with a broad, flat-bottomed horseshoe valley sweeping around it (plate 10). The curving ridge on the hill bears corroborative evidence of the genesis of the topography in the undercut bluffs and slip-off slopes which fit the bends of the horseshoe valley. Starting northwestward from the wagon bridge at Guerneville the three-mile drive around the aggraded horseshoe valley to the river again is full of interest to the observing student of topography. The northern bank of the river at Guerneville at the opening of the two ends of the horseshoe is really the top of a broad natural levee which slopes gently *away* from the river. Undoubtedly it was built up gradually during floods by deposition of sediment as the high water spread northward with slackening current. At the north end of the horseshoe valley there is found a small marsh, the vanishing remnant of the lake that once filled the oxbow cutoff. In time of great floods the river still spreads through the village streets and sets back into the old valley. In the western curve of the horseshoe on top of one of the great redwood stumps may be seen another stump which floated to its present position in a recent great flood. The physiographic significance of the stranded stump lies in the fact that it shows that the land within the oxbow is lower than the banks of the town where the depth of the flood water was not over two feet.

Age of the Cutoff

When first visited by white men the horseshoe bend was one dense redwood forest which later furnished the lumber during the early days of San Francisco. The highest flood plain or lowest terrace of the Lower River is practically continuous with the filled-in surface of the old oxbow. The lumbermen report that some of the trees that were cut showed 2400 rings of annual

growth. The stumps are so weathered that a recount is difficult but the diameter of some of the stumps still standing is eighteen feet, exclusive of the bark. The fact is also vouched for that in removing one of the stumps in making an excavation, the prostrate trunk of a large redwood was found below. The age of the cutoff must be considerably greater than the age of the redwoods. for the period of aggrading necessary to make the lake into good forest land probably exceeded the time for the growth of the forest. Five thousand years may not be an unreasonable time limit for the period since the cutoff, yet it is one of the recent events in the history of the cañon.

Domestic Piracy at Bohemian Grove

A peculiar result of the cutting on the outward curve of a meander loop is found opposite the point near Camp Vacation. Formerly a branch of the railroad crossed on a rather high bridge at this point (plate 9, fig. 1). Looking across the river from Camp Vacation one sees what are apparently two valleys meeting at the end of the bridge and tributary to the river. Actual inspection reveals a stream on the left, Smith's Creek, joining the river through a very short youthful gully, but looking to the right one is surprised to find that the floor of the branch valley slopes gently *away from the banks* of the Russian River, which on this side are nearly sixty feet high above low water. Continuing down this branch valley the noted Bohemian Grove of redwoods is found and here the little valley bends sharply to the right and in half a mile more opens into the Russian River. The Bohemian Valley is a narrow flat-bottomed valley with steep sides rising 400 to 500 feet. The explanation of this peculiar topography is indicated by the sketch map in figure 1 (see page 32). Formerly Smith's Creek did not flow into the river where it does at present, but turned to the left and flowed through Bohemian Grove joining the river just above Monte Rio. The Russian River in its bend at Camp Vacation in the process of undercutting finally broke through the ridge separating it from the bend in Smith's Creek and thus captured the headwaters of that stream, leaving the lower part practically as it is found today. The grade of Smith's Creek is so much greater than

that of the river that at the point of capture the floor of the abandoned portion of Smith's Creek Valley is too high for the flood waters of the river to be diverted even in part to the longer channel through Bohemian Grove.

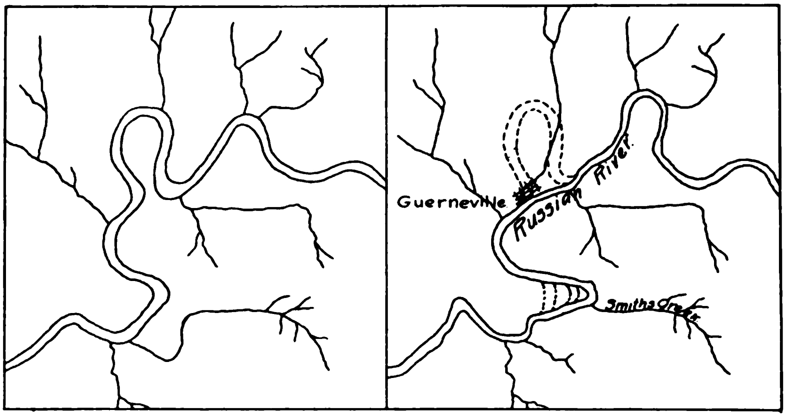

Fig. 1. Sketch map showing on the left the former course of the river and tributaries and on the right the conditions of today.

TERRACES AND OLD WATER LEVELS

It is not to be expected that terraces marking former stream levels in the harder rocks of the cañon of the lower river will be so numerous as in the softer formation of the middle and upper sections. The lowest terrace, some twenty to thirty feet above the river, has already been mentioned and is the remnant of an old flood plain that is still reached by unusually high water. Above this prominent terraces are lacking but there are a few remnants clearly recognized in places. The forest and heavy undergrowth covering most of the slopes mask all the smaller terrace remnants. Patches of stream gravels at various elevations are equally as convincing as fragments of terraces, but the undergrowth is so dense that the search for these is extremely difficult. A large number of such deposits have been found, however, and further search by the trained observer would doubtless reveal many more. Before recording the finding of stream gravels in the valley slopes search was made for nearby conglomerate, the decomposition of which might have accounted for water-worn pebbles.

In studying terraces and other evidences of former stream levels in the cañon of the Russian River, it must be remembered that criteria are different from the criteria used in a valley cut in soft formations where a stream meanders freely on a wide flood plain at each successive stage of uplift. Indications of former water levels are rather to be looked for upon the slip-off slopes only. Practically in every well-marked meander, including the old oxbow at Guerneville, the inner spur has a distinct gravel deposit at an elevation of 100 to 200 feet above the sea. Elevations along the railroad are taken from the engineer's profile sheet, kindly furnished by the officials of the Northwestern Pacific Railroad, to whom acknowledgments are due for many courtesies. Elevations above the railroad have been taken with aneroids graduated to ten feet and checked at frequent intervals by the known levels on the railroad. This eliminated error from the daily variation in the barometer which is well marked on the California Coast.

Allowing a reasonable margin of error in different observers using different barometers, the results of the observations of terrace fragments and of undisputed stream gravels give three well-marked old stream levels. The majority of these observations have been checked by the writer in person. The elevations are recorded from sea-level as a base and the field observations consistently give somewhat higher elevations for the same stream level at places further up stream.

The three main levels are approximately 100-120, 225-240, and 400-440 feet above sea. For those familiar with the local names in the cañon the following data may be of interest. The 100-120 foot terrace may be found below Markham's, on the trail running up the ridge at Camp Vacation, and the Southside Farm at Guerneville. The 200-240 foot level appears at Duncan Mills, on the Camp Vacation trail, above the Southside Farm, on the cemetery hill at Guerneville, and at the mouth of Mark West Creek. The 400-440 level is to be found below Duncan Mills and is also marked by a distinct patch of coarse gravel west of Camp Vacation opposite Monte Rio. This list of places is far from exhaustive and is given merely to suggest the most accessible localities for verifying the observations.

A number of other observations do not fall into well-established groups and probably represent but short periods of rest in the process of elevation. Osmont[16] speaks of well-defined terraces up to 350 feet above the present flood plains as having been formed by streams in the synclinal valleys such as Santa Rosa and Sonoma, but gives no specific locations. In the Santa Rosa Valley the writer judges that the highest terrace referred to by Osmont corresponds to the 400-440 foot level measuring from sea-level.

Recent Subsidence

The subsidence which caused the formation of San Francisco Bay has affected to some extent the Lower River. Defining this depression in general terms Lawson limits the area affected as follows:

> The sag appears to extend a little beyond Bodega Head on the north, but does not materially affect the Russian River. We may safely suppose it to feather out at the latter point.[17]

No exception is to be taken to this statement as a general proposition concerning a large area, but for the more detailed study of the present paper attention should be called to the fact that the tide is felt at Duncan Mills about eight miles from the mouth of the river. The water near the mouth is deep enough to carry the coast lumber schooners which formerly used a landing four miles from the mouth. A bar is annually extended across the mouth by the influence of the north-flowing Davidson Inshore Eddy current during heavy winds and is annually opened by the winter floods, unless it is sooner cut by man to allow fish to run upstream. Figure 1, plate 11, is taken looking southward across the river. The bar is open and the tide is running in. Across the river are seen remnants of a dissected ocean terrace. The drowned character of the Lower River is well shown in the tributaries. Figure 2, plate 11, is a view of Willow Creek looking upstream. Very evidently the valley has been depressed and filled up with sediment and the creek now meanders in the new-

16 Univ. Calif. Publ. Bull. Dept. Geol., vol. 4, p. 80.

17 Univ. Calif. Publ. Bull. Dept. Geol., vol. 2, p. 267.

made land. The extent upstream to which recent subsidence can be traced is doubtful, but it is probably less than the reach of the tide.

There are also evidences of subsidence along the lower portion of Laguna de Santa Rosa, a creek which flows northerly along the west side of Santa Rosa Valley, emptying into Mark West Creek about two miles above the junction of the latter with Russian River as shown on the map, plate 1. From Sebastopol to Trenton the valley of Laguna de Santa Rosa is plainly a recently filled area through which a series of lagoons and tule marshes mark the channel of the sluggish current. For definite information concerning the depth of the lagoons the writer is indebted to four physiography students in the high school at Sebastopol. Through the courtesy of Miss Edith Tracy, the teacher of Physical Geography, the boys undertook the mapping and sounding of the two main lagoons. The following extract from their report concerning the lagoon immediately north of Sebastopol furnishes interesting data and also internal evidence of the reliability of their work:

Equipped with 500 feet of strong line and a one-pound solid lead sinker, the work was commenced. The task of making the soundings lasted from 11 o'clock a.m. to 3:30 p.m. During this time 56 soundings were made. Beginning at the south end, in a narrow slough, we found the first depth to be 5½ feet. At the place where the slough broadened into the larger part the depth was 9 feet. In 100 yards' distance the depth increased gradually to 23 feet. From the place where the stream reached the depth of 23 feet, for ¾ of a mile, the depth varied from 20 to 23½ feet. The greatest depth was 23½ feet.

The bottom of the lake is a very soft, black mud, into which the sinker sank quite readily.

We had spoken of our work of sounding to several and were told of certain places where the depth of 60 feet had been reached. We resounded these places and found no place more than 20 feet.

Ballard Lake, about six miles to the northward, is the last of the well-defined lagoons, and is described as about one-fourth of a mile long and two hundred and fifty feet wide. The maximum depth reported is twenty-five feet. Dead oaks, apparently killed by the water, are still standing in the marsh around this little lake.

Ballard Lake is just above the junction of Laguna de Santa Rosa with Mark West Creek, and, similarly, the lagoon at Sebastopol is upstream from the mouth of Santa Rosa Creek. The boys attributed both lagoons to the deposits from these two creeks obstructing the flow of Laguna de Santa Rosa, a very reasonable hypothesis, but the field evidence suggests other contributing causes.

Mark West Creek below the mouth of Laguna is without perceptible slope. The railroad which follows the bank is marked level on the profile of grades furnished by the chief engineer of the Northwestern Pacific. Trenton and a little flag station some four miles below have exactly the same elevation, sixty-three feet above the sea. Just below this station the railroad crosses Russian River. Measuring from the track on the bridge the level of the river surface at ordinary flow is from twenty-five to thirty feet above the sea.

Mark West Creek at the mouth of Laguna is fully fifteen feet below the railroad grade or about fifty feet above sea-level. The surface of Ballard Lake is practically the same level, which makes the lowest portion of the lagoon basin less than thirty feet above the sea. Formerly the bed of the lagoon must have been still lower, as is evidenced by the recent deposits of soft mud. Comparing this level with the level of the present bed of the Russian River over five miles below the lagoon, recent depression of the basin of the lower Laguna de Santa Rosa is plainly indicated. The delta deposits from Mark West and Santa Rosa Creeks, instead of being the cause of the lagoons, would thus become, like the lagoons themselves, the result of the subsidence.

It should be remarked that the chief interest in the evidence of subsidence in this vicinity lies in the fact that the depressed area is practically along the axis of the Santa Rosa Valley syncline, thus indicating that downward folding has taken place in time so recent as practically to be termed present time. Immediately after the earthquake of 1906 many reports were current of earth movements within this area. The writer examined the valley carefully at that time, but found only the secondary cracks that were common in all water-filled alluvial deposits within fifteen to twenty miles of the San Andreas Rift. There was no

evidence of any changes of level aside from very minor areas of extremely local slumping.

The physiography to the northward of Mark West Creek furnishes no evidence of subsidence. It may be a related fact that fifteen miles southeastward of Sebastopol the level of the railway station at Petaluma, twelve miles from San Pablo Bay, is only ten feet above the sea.

Genesis of the Lower River

The detailed description of the Lower River is in harmony with the theory advanced that this portion of the river is part of an old stream existing when the whole region was near sea-level. In other words, this portion of the river was antecedent to the last great uplift. Judging from its direction of flow normal to the ocean, this old stream was consequent upon the slope of the land at the time. The head was presumably Mark West Creek, which lies in the direct upstream extension of the Lower River. This creek in the floor of Santa Rosa Valley bears no resemblance to the Lower River but its upper portion in the hills to the eastward runs in a cañon that approximates the Lower River Cañon in size and in general characteristics. While the bottom of the cañon is narrower and carries less water the walls rise from 600 to 700 feet. The probability is strong that the present Middle River was a tributary of the old river which since the uplift has developed the long subsequent branch to the northwest, that branch now being the Upper River of the main stream.

Resemblance of Lower River to Big River

Attention has been called to the consequent drainage still persisting on the slope of the Mendocino Plateau. Among these streams, the largest, Big River, seems to be the correlative of the former consequent Russian River in size and in general characteristics. Its lower course has very pronounced meanders and is evidently at very low grade as the tide runs up the river for six or seven miles at least. An unverified report from the lumbermen states that the tide is felt for eighteen miles from the sea.

Big River differs from the former Russian River in history and in topographic conditions. The former has no synclinal

valley filled with softer sediment and lying across its upper course as does the Santa Rosa Valley across the latter. Big River also differs in having failed to develop a long subsequent tributary as did the Russian River. Attention is called to Big River not merely because in itself it offers promise of affording an interesting physiographic problem, but primarily because it seems to be the exact type of the original short consequent Russian River.

CONCLUSION

In attempting to summarize the history of the Russian River in its various parts the limitation noted in the introduction, namely, the lack of maps showing the topography and the areal geology, necessarily limits definiteness of statement in any conclusions stated. In briefly recapitulating the conclusions already offered in the discussion of the various sections some comment will be made concerning their probability or concerning possible alternative hypotheses.

The Lower River is termed antecedent and is considered the remnant of a former consequent coast stream which has held its position despite the slow uplift. It is possible that much of it flowed over the soft recent deposits and by the removal of that series has been let down upon older rocks in which it now flows. Technically such a history may justify the use of the term "superimposed," but in no place is the present river out of harmony with the minor topography in the way that the Middle River is in various places. The antecedent condition of the Lower River fully accounts for its leaving the open Santa Rosa Valley and crossing the western highland in a cañon. The Lower River is then termed antecedent as apparently a sufficient explanation. If superposition of the river upon the Merced series ever existed it has not resulted in any relations that are not explained by its mere antecedent character.

The Middle River in its peculiar cutting off of the point of a ridge in Alexander Valley, in its course through Fitch Mountains, and in incising its channel on the slope of Santa Rosa Valley, exhibits the characteristics of a superimposed river—a conclusion justified by the existence within the area of patches

of the softer and later series through which the Middle River has cut down to its present position.

The Upper River has the marks of the typical subsequent river, but detailed study of the areal geology is needed to reveal the exact nature of the line of weakness along which the former tributary has developed until its size justifies its being regarded as part of the trunk of the main river today. The gravels of the Upper River may, on further study, indicate that portions of it may to some extent be superimposed on older structure below. The history of the Upper River is complicated also by its capture and by its reversal of portions of the streams of the Mendocino Plateau.

PLATE 1

This drainage map of the Russian River is compiled from the county maps of the region. To outline the basin, the river and its tributaries are printed in broader lines than the drainage in adjacent areas. The location of each of the photographs reproduced in the following plates is indicated on the drainage map by an index letter and arrow showing the direction in which the camera pointed.

PLATE 2

Fig. 1. Location, A on plate 1. The photograph is taken looking diagonally across Yorkville Pass on the crest of Mendocino Range. The nearly level fields are at an elevation of over one thousand feet and are considered to be a portion of the valley floor of Navarro River before it was beheaded by Russian River.

Fig. 2. Location, B on plate 1. The view is taken from the right hand slope of Yorkville Pass as seen in the figure above and shows the extension of the valley floor of the former Navarro River now dissected by the headwaters of a tributary of Russian River.

PLATE 3

Fig. 1. Location C on plate 1. The lower part of Big Sulphur Creek, the beheaded portion of Navarro River. The youthful form of the cañon is due to the rejuvenation consequent upon capture by Russian River.

Fig. 2. Location, D on plate 1. Characteristic gravel deposits of the upper Russian River. The view shows a portion of the dissected front of the 240-foot terrace opposite Ukiah.

PLATE 4

Fig. 1. Location, E on plate 1. A portion of the valley floor north of Ukiah. The ridge in the right center has a very smooth level top and is a portion of the 240-foot alluvial terrace.

Fig. 2. Location, F on plate 1. Potter Valley at the head of the east fork of Russian River. There are several of these intermontane valleys in the northern coast ranges. Their history has not yet been worked out.

PLATE 5

Contrast in appearance of the Upper and Middle portions of the Russian River.

Fig. 1. Location, G on plate. The narrow and still youthful valley of the Upper River a few miles north of Cloverdale.

Fig. 2. Location, H on plate 1. The view is taken diagonally across the head of the valleys of the Middle River opposite Cloverdale. The gorge of the Upper River terminates at the point of the ridge in the right center.

PLATE 6

Location, I on plate 1. A portion of the superimposed part of the Russian River in Alexander Valley. The river has cut the depression through the ridge in the left center (indicated by the sag in the skyline of the ridge), although the low valley floor on the right is continuous around the point of the ridge to the river banks beyond.

PLATE 7

Fig. 1. Location, J on plate 1. A distant view of the northern portion of the broad Santa Rosa Valley. Russian River enters this valley from the right, but instead of following the axis of the valley to the sea level near Petaluma it crosses the valley and flows for several miles in a channel incised in the western slope of the valley. Photograph by Mr. Roger Sprague.

Fig. 2. Location, K on plate 1. The channel of the Russian River, incised in the west slope of the valley, is seen on the extreme left. The low hills bordering the river are over 200 feet higher than the Santa Rosa Valley floor to the immediate right of the view.

PLATE 8

Contrasted views of the cañon of the Lower River and of the low alluvial plain which today would seem to be the natural course of the stream to sea level at San Pablo Bay.

Fig. 1. Location, L on plate 1. The entrenched meanders of the Lower River in the dissected plateau near Guerneville. Elevation of plateau remnants 800 to 1200 feet.

Fig. 2. Location, M on plate 1. The Santa Rosa Valley floor near Cotati station, elevation 113 feet. The banks of Russian River 18 miles to the northwest near Healdsburg are 99 feet in elevation.

PLATE 9

Detail of the entrenched meanders of the Lower River.

Fig. 1. Location, N on plate 1. The bend at Camp Vacation just below Guerneville. The lateral cutting of the river has here captured Smith's Creek, which formerly joined the river two miles down stream beyond the hill occupying the central distance. See fig. 1, in the text, page 67.

Fig. 2. Location, O on plate 1. Bend just east of Guerneville. The field in the foreground shows the amount of lateral cutting since the river has been at approximate baselevel.

PLATE 10

Location, P on plate 1. The oxbow cutoff at Guerneville. The hill in the center view lies within the abandoned meander. The course of the river was formerly northward on the right of the central hill, then passing behind it the return was through the flat on the left. The present river channel is in the rear of the point of view.

PLATE 11

Drowned topography at the mouth of Russian River.

Fig. 1. Location, R on plate 1. The lagoon at the mouth of the river and the bar which frequently completely closes the river.

Fig. 2. Location, S on plate 1. The aggraded alluvial valley of a tributary nearly three miles from the ocean.

UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY

Vol. 1, No. 2, pp. 63-79 April 9, 1913

THE RAINFALL OF BERKELEY, CALIFORNIA

BY

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CONTENTS

INTRODUCTION

The rainfall record of Berkeley, California, kept by the University of California, now covers a period of twenty-five years; and, although the exposure of the rain-gage has at no time been ideal, the record as presented is of considerable value as showing the general tendencies of the rainfall conditions and is probably consistent with itself. The United States Signal Service, which was at that time in charge of the meteorological work carried on by the government, established a voluntary observer's station at the Student's Observatory when this activity was undertaken at Berkeley in 1886. Until 1912 the meteorological work of the University was carried on by the Observatory, the coöperation continuing with the United States Weather Bureau, to which the meteorological work of the Signal Service was transferred in 1891. The observations have been made in accordance with the instructions of the Weather Bureau and the results

Fig. 1

Map showing the location of Berkeley

From the Report of the State Earthquake Investigation Commission, Carnegie Institution, Washington, 1908

have been published in the Monthly Weather Review and the Climatological Reports. The official figures of the Berkeley rainfall, furnished by the Weather Bureau, have been used for this report; the observations were all made by the University and reported to the Weather Bureau, where the figures have been recorded and corrected where necessary. These data form a homogeneous and consistent record of the rainfall for the period under discussion.

The University campus is situated on the eastern or shoreward edge of a narrow coastal plain on the eastern side of San Francisco Bay. The relations of the locality to the geographic

features are shown by the map, figure 1. That part of the coast ranges known as the Berkeley Hills, rises abruptly from the campus, where the elevation is about 300 feet (ninety meters), to an elevation of over 1000 feet (300 meters) in less than half a mile (one kilometer) and reaches nearly 2000 feet (600 meters) in two miles (three kilometers). The plain slopes gently westward from the campus to the Bay, about two miles distant. The University is twelve miles (nineteen kilometers) east-north-east from the Golden Gate and the Pacific Ocean. The canyon of a small stream opens from the east on the campus, but this canyon cuts only the western line of hills and does not open a passage through to the valleys to the eastward.

EXPOSURE OF THE RAIN-GAGE

The rain-gage has always been located at the Observatory building, which is situated in the northern part of the University grounds about a quarter of a mile from the foot of the Berkeley Hills, on a slight elevation rising somewhat abruptly from a shallow valley which crosses the campus from east to west; there is, however, no canyon through the hills east of this valley. The first rain-gage, the style of which is not stated in the record, was set up October 16, 1886, in a framework over a portion of the building at a height of twenty-one feet above the ground. Comparisons, made in December, 1889, with a gage designed as a "bulletin gage," showed that the record was somewhat inaccurate and a new gage of the United States Weather Bureau pattern was placed in service about January 1, 1890; this gage has continued in use to the present. From September, 1892, to September, 1899, the gage was exposed with its top twelve inches above the ground north of the Observatory building; the distance from the building is not stated in the record. About October 1, 1899, the gage was removed to the roof of the building at a height of fifteen feet above the ground and it has remained in that position ever since.

The question of the exposure of rain-gages is exceedingly complicated. The ideal exposure is on the ground in an open space of considerable size where the catch will not be interfered with by the growth of trees or shrubs, or by the proximity of

buildings. Roof exposure of the gage generally gives readings below the true rainfall, especially where the roof is not large; but local conditions may necessitate roof exposure either because of lack of suitable ground space, as is not uncommon in large cities, or because of the possibility of interference with the gage. The growth of trees around the observatory building may have had some effect on the catch of the gage but, as these trees are not close to the roof where the gage is exposed, the probability of decreased catch by direct sheltering is slight and the trees may be of value in protecting the gage from wind and this would tend to make the catch of the gage the same as the true rainfall. The conditions of exposure seem to have been comparable throughout the period as the record does not show breaks in continuity when the exposure was changed. It may, therefore, be confidently asserted that the record is of sufficient value and homogeneity as to conditions of exposure and manner of treatment of observations to stand as representative of the rainfall conditions of the eastern shore of San Francisco Bay for the twenty-five years which it covers.

MONTHLY RAINFALL

Table I shows the amount of precipitation for each month of the twenty-five years from July 1, 1887, to July 1, 1912, and also the monthly means based upon this period, and the amount of precipitation by rainfall years ending on June 30 in each case. The dry summer and the occurrence of most of the rain in the winter months make it desirable to use this rainfall-year rather than the calendar year. The rainfall of the autumn months belongs properly with that of the following winter and spring and not with that of the early part of the same calendar year.

The mean monthly amounts show the seasonal character of the precipitation; this type of rainfall, which is known as "subtropical," is characterized by a dry summer and rainfall under cyclonic control in the winter months. The distribution of the rainfall through the year may be shown graphically as in figures 2 and 3, on pages 71 and 72, which give the mean monthly rainfall in inches and as per cents of the mean annual amount. The

TABLE I

Monthly and Seasonal Rainfall of Berkeley, California

Season	July	August	September	October	November	December	January	February	March	April	May	June	Seasonal	% of seasonal mean
1887-88............	0.01″	0″	0.40″	0″	0.76″	2.94″	5.84″	1.92″	4.50″	0.20″	0.42″	0.50″	17.49″	66
1888-89............	T	0	0.59	0.02	2.71	3.79	0.78	0.54	7.58	0.72	1.50	0.06	18.29	69
1889-90............	0	0	0	5.80	2.39	12.59	11.16	5.70	4.74	2.18	1.44	T	46.00	173
1890-91............	0	T	0.25	0	0	3.32	1.13	10.68	3.17	3.42	1.61	0.38	23.96	90
1891-92............	0.44	0	0.74	0.18	1.01	6.22	2.34	4.20	3.60	1.68	2.97	0	23.38	88
1892-93............	0.01	0	0.07	1.99	5.35	6.64	3.90	3.28	6.19	1.62	0.26	0	29.31	110
1893-94............	0	0	0.38	0.52	5.22	2.62	9.54	3.77	0.91	0.57	2.01	1.11	26.65	100
1894-95............	0	0	1.61	3.29	1.85	12.63	10.88	3.25	2.64	2.30	1.06	0	39.01	147
1895-96............	0.04	0	1.28	0.07	1.78	2.20	11.40	0.36	2.93	6.72	0.94	0	27.72	104
1896-97............	T	0.90	0.76	1.91	5.15	4.92	3.71	4.68	5.97	0.44	0.20	0.30	28.94	109
1897-98............	0	0	0.20	2.48	1.58	2.71	1.54	3.28	0.31	0.19	1.87	0.24	14.40	54
1898-99............	0	0.04	0.93	1.88	0.97	1.22	5.90	0.22	13.19	1.56	1.70	0.05	27.66	104
1899-00............	0	T	0	5.26	5.85	3.46	4.18	1.02	3.00	1.58	0.91	0.08	25.34	96
1900-01............	0	0.02	0.05	1.41	5.04	1.83	5.86	5.91	0.91	3.06	1.02	0	25.11	94
1901-02............	0	0	1.30	0.68	3.16	1.48	1.36	10.47	4.17	1.55	1.69	0	25.86	97
1902-03............	0	T	0	2.35	3.21	3.69	5.17	2.05	7.81	1.11	0.02	T	25.41	96
1903-04............	0	0	0	0.50	5.89	2.19	1.40	10.45	11.04	2.10	0.02	T	33.59	126
1904-05............	0	0.07	4.44	3.39	2.23	2.03	5.58	2.56	4.25	1.37	3.43	0	29.35	110
1905-06............	0	0	0	0	1.46	2.22	6.92	3.96	9.05	0.74	2.56	0.64	27.55	104
1906-07............	0	0.04	0.17	T	1.64	7.24	5.02	5.36	10.76	0.36	0.04	1.24	31.87	120
1907-08............	0	0	0.06	1.54	0.08	4.84	5.44	4.35	1.37	0.30	1.17	0.01	19.16	72
1908-09............	0	0	0.09	0.98	1.83	2.62	13.11	9.26	3.64	0.02	0	0	31.55	119
1909-10............	0	0	0.78	1.34	3.43	7.24	3.38	1.85	3.82	0.41	0.01	0.02	22.28	84
1910-11............	0	0	0.06	0.60	0.87	1.80	15.99	4.05	5.17	1.56	0.27	0.04	30.41	114
1911-12............	T	0	T	0.78	0.46	2.51	3.65	0.54	2.96	1.47	1.56	0.85	14.73	55
Means	0.02	0.04	0.57	1.48	2.54	4.20	5.81	4.15	4.95	1.49	1.15	0.22	26.60	100

month of July is practically rainless; precipitation was recorded but seven times in the whole period. The mean monthly amount is 0.02 in. (0.5 mm.), which is almost entirely due to a single fall in 1891, when 0.44 in. (11.2 mm.) fell in one day. The other precipitation in July is nearly negligible in amount, and is largely from the condensation of fog in amounts barely sufficient to be measured. The conditions of the August rainfall are about the same as those of July; significant amounts have been recorded a little more frequently; but, except for a fall of 0.84 in. (21.3 mm.) in one day in 1896, this precipitation is largely the result of condensing fog.

The rainy season in Berkeley is generally preceded by light rains in September and October. In twenty-five years but three of the Septembers have been rainless. The amount has exceeded one inch (25 mm.) only four times in the period. The heaviest fall for any September was 4.44 in. (122.8 mm.) during the month of September, 1904. The average rainfall for the month is slightly over half an inch (13 mm.). The average rainfall for October is nearly three times that for September, or nearly an inch and a half (38 mm.). In three Octobers no rain was recorded and in twelve the amount was more than one inch (25 mm.). In 1889, 5.80 in. (147.3 mm.) and in 1899, 5.27 in. (133.9 mm.) fell in October; these are the only years in which the precipitation equalled or approached five inches (127 mm.).

The average rainfall for November is 2.54 in. (64.5 mm.) and this month may be said to mark the usual beginning of the season of heavy rainfall; although, of course, the beginning is not sharply defined and varies a good deal from year to year as the table shows. Precipitation has been recorded in all the Novembers except that of 1890; and in only one other case was the amount less than a tenth of an inch (2.5 mm.). One inch (25 mm.) or more was recorded in all but five cases, and over five inches (127 mm.) fell during the month in six of the years of the record. The maximum amount recorded for November was 5.89 in. (149.6 mm.) in 1903.

December is one of the months of heaviest rainfall, with a mean for the month of 4.20 in. (106.7 mm.). The minimum for the period is 1.22 in. (31.0 mm.) in 1898; the maximum was

12.63 in. (320.8 mm.) during December, 1894, the amount in December, 1889, was but 0.04 in. (1.0 mm.) less. The amount for the month exceeded five inches (127 mm.) in six of the years, and was more than ten inches (254 mm.) twice during the period of the record.

The average rainfall for January is 5.81 in. (147.6 mm.), which amount exceeds the average for any other month by 0.86 in. (21.8 mm.). Only once in the twenty-five years of the record, in 1889, did less than an inch (25 mm.) fall during the month; the amount for this year, 0.78 in. (19.8 mm.) is the minimum. In fourteen of the Januarys the amount of precipitation exceeded five inches (127 mm.), and in five the amount was over ten inches (254 mm.). The maximum is 15.99 in. (406.2 mm.) which was recorded in January, 1911; this is the maximum amount for any single month during the period.

February has a mean rainfall of 4.15 in. (105.4 mm.) which is decidedly less than that of January or of March. This is in part due to the shorter month; but that the number of days is not wholly responsible for this falling off is shown in Table II, on page 73, in which the last column gives the average amount of rain for each day of the month and thereby eliminates any influence which the length of the month may have upon the mean monthly rainfall. Less than half an inch (13 mm.) was recorded during the month in two years, 0.22 in. (5.6 mm.) in 1899 being the minimum for February; in only three cases was the amount for the month less than one inch (25 mm.). The precipitation exceeded ten inches (254 mm.) but three times; the maximum was 10.68 in. (271.3 mm.) in 1891.

The mean rainfall for March is 4.95 in. (125.7 mm.) and this month is second to January in mean monthly rainfall. The minimum was 0.32 in. (8.1 mm.) in 1898, which was the only year in which less than half an inch (13 mm.) fell during the month. Ten inches (254 mm.) or more was recorded in only three cases. The maximum amount was 13.19 in. (335.0 mm.) in 1899, which amount was not exceeded in any month except January, 1911. The end of the marked rainy season comes rather abruptly with the end of March, although rains are not unusual in April and May.

The mean amount of rainfall for April shows a decided falling off from that of March. The average for April is about an inch and a half (38 mm.); there is also a marked decrease in the maximum amount for a single month from 13.19 in. (335.0 mm.) for March to 6.72 in. (170.7 mm.) for April. This amount occurred in April 1896, and is the only case in which five inches (127 mm.) was exceeded during the month in twenty-five years. The minimum rainfall for April is 0.02 in. (0.5 mm.) which was recorded during April, 1910. The May rainfall has the same characteristics as that of April. The mean amount is 1.15 in. (29.2 mm.) which is slightly smaller than that of April. The maximum, 3.44 in. (87.4 mm.) in May, 1905, is little more than half the maximum for April. May, 1909, was rainless, but precipitation was recorded in all the other Mays. It is interesting to note that the precipitation for May was above normal in the two driest years, 1897-98 and 1911-12. June has the characteristic of a summer month, with a mean rainfall of 0.23 in. (5.8 mm.). Of the twenty-five Junes, eight are recorded as rainless. The maximum rainfall for June was 1.24 in. (31.2 mm.) in 1907 and in only one other case did the amount exceed one inch (25 mm.).

The average conditions are graphically shown by figures 2 to 5. In figure 2 the annual march of rainfall in inches for each month is plotted around a center representing zero and the circles are drawn for each inch of rainfall. The twelve radii show the months of the year. The mean rainfall for each month is indicated by the distance from the center of the figure to the edge of the shading on the radius for that month. The arrangement of the months around a circle serves to show the continuity of the year and to avoid breaks between successive months, which is necessary if a straight-line diagram is used. It is not logical to break the figure in the middle of the rainy season at the end of the calendar year; and scarcely less so during the summer months when rain is rare. The average conditions of rainfall and other meteorological factors are continuous and there is always a weakness in a curve which has a beginning and an end. The only type of diagram which avoids this difficulty is one in which the months are arranged around a circle. This type is used in

figure 2 in spite of its unusual appearance and disadvantages in showing slopes, in the hope that the continuity of conditions of rainfall may be more clearly shown. The other diagrams have been drawn in the more common manner partly because of the difficulties inherent in a circular figure in cases where the slope of the line is an important factor.

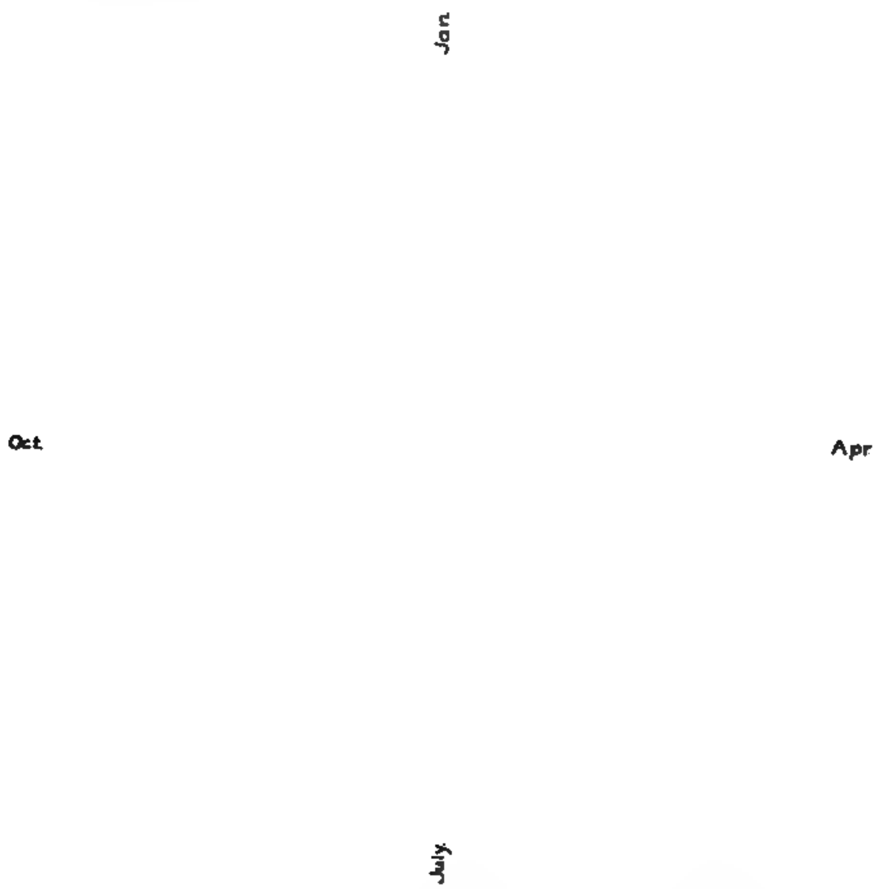

Fig. 2

Mean monthly rainfall in inches at Berkeley, California

Figure 2 shows the occurrence of the greater part of the rainfall in the winter half year and the almost total absence of precipitation during the summer months. While this figure

shows the abrupt ending of the rainy season with the end of March and the more gradual beginning from October to December, these facts appear more clearly from figure 3 in which the mean rainfall for each month is plotted as a per cent of the mean annual amount. In such a diagram, of course, the actual amounts of precipitation are not considered but merely their relation to each other. This diagram also serves to show the falling off in the rainfall for February and the increase again

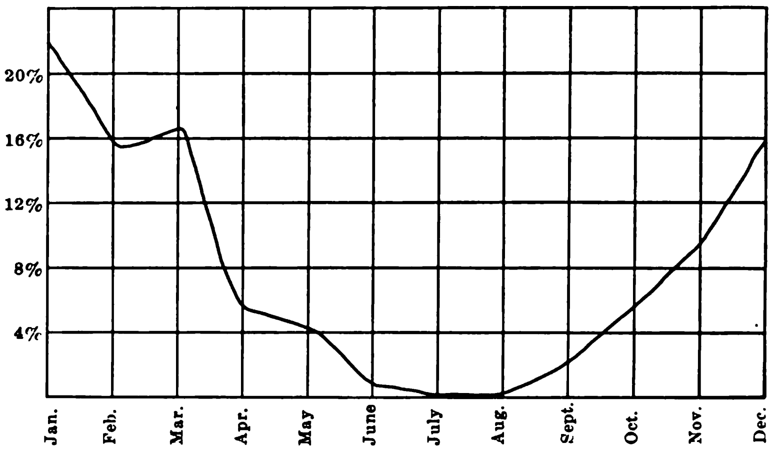

Fig. 3

Monthly rainfall in per cents of the mean annual amount at Berkeley, California

for March. This decrease in February has led to the construction of figure 4, where the rainfall for each month is plotted as the average amount for each day of the month so that the differences in the number of days in the several months might not affect the mean amount of rainfall. This was accomplished by dividing the mean rainfall for each month by the number of days in that month. The result is shown numerically in Table II. As would be expected the falling off in February is not as great when the data are corrected in this manner, but figure 4 shows that even this correction does not entirely eliminate the falling off for the month. The smaller amount of rainfall at this time in the year must be regarded as real as far as the data for Berke-

ley may be relied upon for the twenty-five years of observations, but whether this is due to accidental conditions of exposure, or to imperfections in the exposure or the record cannot be determined from the data for this one station alone. If the three years in which the February rainfall is abnormally small are omitted, the average for the month shows, when corrected for the number of days in the month, an amount between that of January and March. This probably may be interpreted as showing that the period of twenty-five years under consideration is not long enough to establish a true mean for the month.

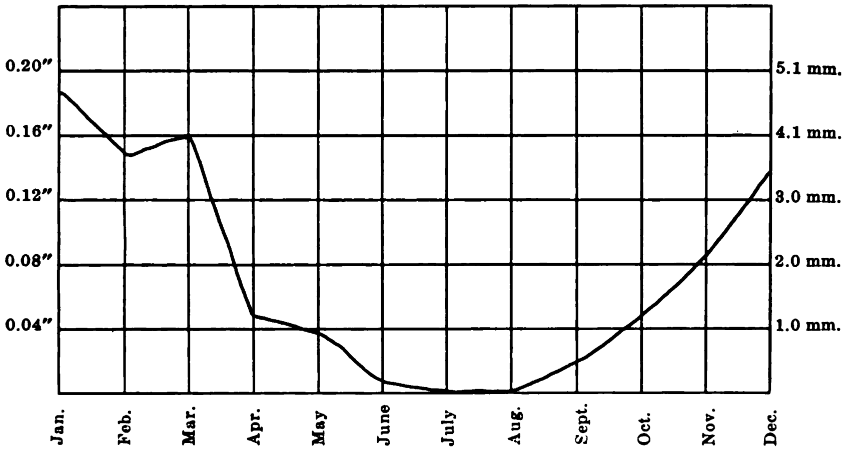

Fig. 4

Mean amount of rainfall per day at Berkeley, California

TABLE II

RAINFALL OF BERKELEY, CALIFORNIA, FROM TWENTY-FIVE-YEAR MEANS

	Mean for per month	Total from July 1	Per cent of annual	Average per day
July	0.02″	0.02″	0.1	0.0006″
August	0.04	0.06	0.2	0.0013
September	0.57	0.63	2.1	0.0190
October	1.48	2.11	5.6	0.0477
November	2.54	4.65	9.5	0.0847
December	4.20	8.85	15.8	0.1355
January	5.81	14.66	21.9	0.1874
February	4.15	18.81	15.5	0.1483
March	4.95	23.76	18.6	0.1597
April	1.49	25.25	5.6	0.0497
May	1.15	26.40	4.3	0.0371
June	0.22	26.62	0.8	0.0073
Year	26.62	26.62	100.0	0.0729

The accumulated amounts of precipitation are shown by figure 5, in which the mean amount of rainfall for the season from July 1 to the end of each month has been plotted for that month. This curve shows the average amounts received up to the end of any month and how the total amount of precipitation for the year is made up from month to month until the annual amount is reached. In the winter months when the rainfall is heavy the curve is steep; and when the precipitation is light or wanting, as is the case in the summer, the curve becomes flat. This type of diagram also shows the beginning and ending of the rainy season as do the others.

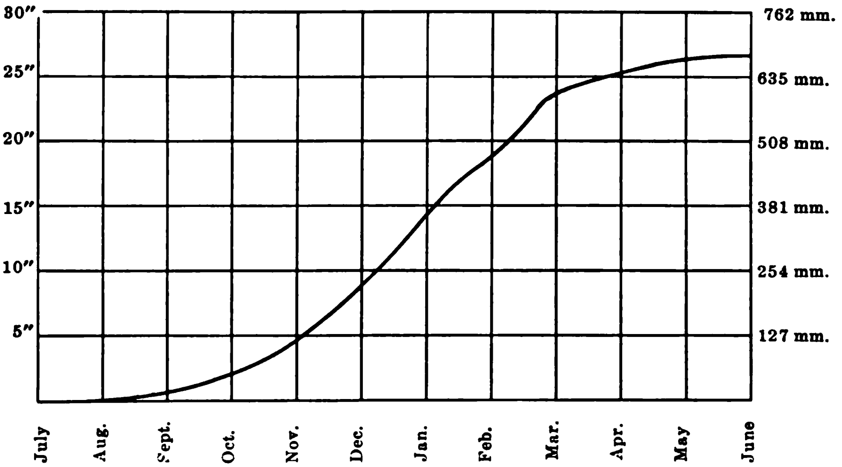

Fig. 5

Mean accumulated seasonal rainfall at Berkeley, California

ANNUAL RAINFALL

The mean annual rainfall for the twenty-five years of the record is 26.60 in. (675.6 mm.). This amount has been exceeded in twelve years and not reached in twelve. In but one year of the whole period was an amount within three per cent of the mean annual amount recorded; this was in 1893–94 when the amount for the rainfall year was 26.65 in. (676.9 mm.). The maximum rainfall in any one rainfall year was 46.00 in. (1168.4 mm.) in 1890–91, which is 173 per cent of the mean for

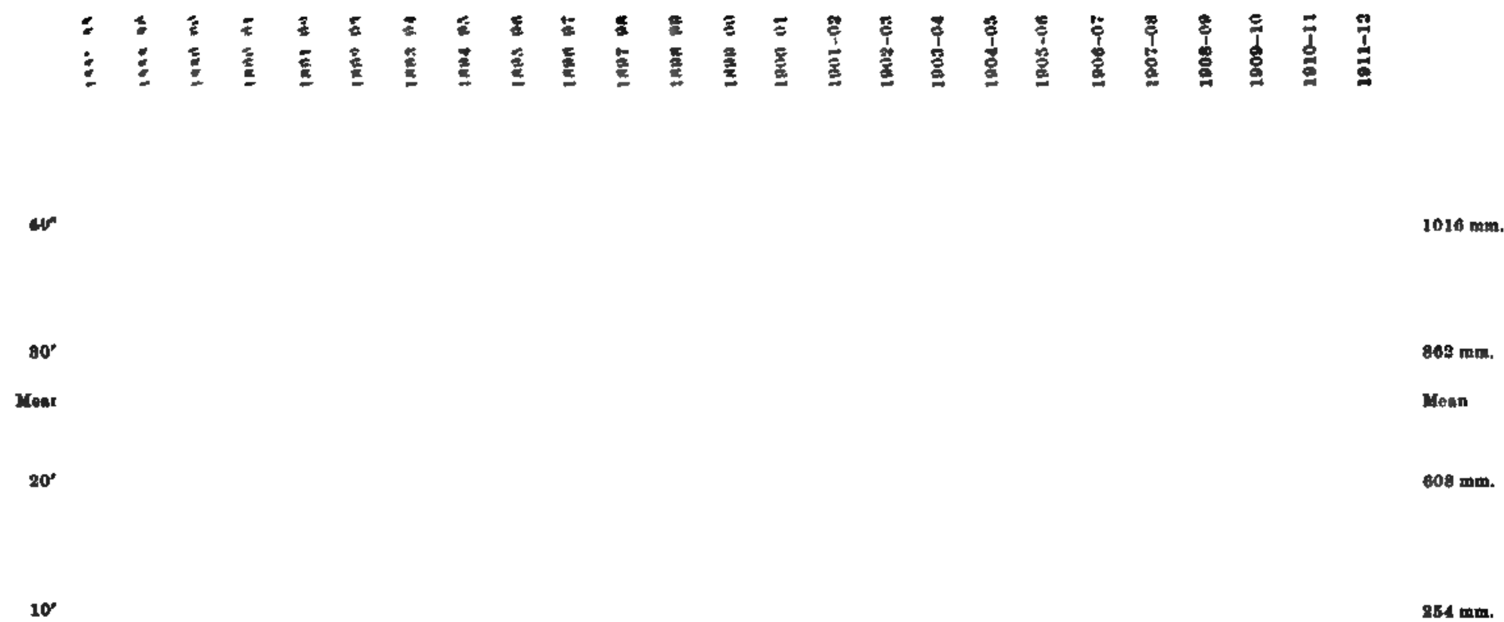

Fig. 6

Precipitation at Berkeley, California, by rainfall years ending July 1st, from 1887 to 1912 inclusive

the period of the record. This is the only year in which more than forty inches (1000 mm.) fell; but thirty-five inches (889 mm.) was exceeded in 1894–95, and there was over thirty inches (762 mm.) in four years besides these two. In the whole period no year of large excess has been immediately followed by another such year, a fact which stands out more clearly in figure 6, although the same information is to be found in Table I. The smallest amount of precipitation in any rainfall year was 14.40 in. (365.8 mm.) which occurred in 1897–98, this is only 54 per cent of the mean amount; in 1911–12 but 55 per cent of the mean was recorded.

The years of excess and deficiency stand out clearly in figure 6, in which the total rainfall for each year from the beginning of the record has been plotted. The line above the 26.00 in. (660 mm.) mark shows the mean of the twenty-five years. Probably the most conspicuous conditions shown by this diagram are the occasional wide departures from the mean, which are shown in per cents of the mean in Table I. There are four years of marked excess, and five of marked deficiency of rainfall. The smaller excesses in 1908–09 and 1910–11 are conspicuous not so much because of their magnitude as because of the deficiencies in the amounts of the years immediately preceding and following.

The last five years, that is the period since 1907, give an incorrect idea of the general conditions as these years show more irregular and wider departures from the mean than is usual throughout the period. The five years from 1887 to 1892 show, perhaps, as wide departures but they are much more regular as all the years of this period except 1889–90 were years of deficient rainfall. The dry year of 1897–98 was preceded by two years in which the rainfall was not far from the mean for the whole period, and was followed by five years of slight departure. Each of the other years in which the deficiency was considerable, except 1887–88, was preceded and followed by years in which the precipitation was in excess of the average. The supply of water available for the University swimming pool at Berkeley, during the summer and fall of 1912, before the beginning of the rains, was so small that it was found necessary to close the pool. As this swimming pool was not completed until

April, 1911, it is not possible to compare this condition with that of other dry years. The water supply is all from the Berkeley Hills where the drainage area covers about one square mile.

OSCILLATIONS IN RAINFALL

In a diagram like figure 6 the differences between the individual years are so great that any tendencies extending over a period of years are apt to be obscured. In order to determine whether the Berkeley record shows any such tendencies some sort of smoothing is necessary. Smoothing may be accomplished by various methods, and the method of smoothing is of such importance that the final result of all smoothed curves must be regarded as more or less biased. Inspection of figure 6 shows that the differences are so great that it is nearly or quite impossible to draw a free-hand curve which will give a correct idea of the tendencies; smoothing by some sort of formula becomes necessary if the curve is to be smoothed at all. Smoothing in this manner may be accomplished in a number of ways, but all of them have for a foundation the averaging of groups of years and the substitution of the average of the group for the figures for a definite year. The curve of annual precipitation for Berkeley has been smoothed by Blandford's formula $\frac{A + 4B + 6C + 4D + E}{16} = C'$,[1] and by the formula $\frac{B + C + D}{3} = C'$, where the letters represent the precipitation for successive years, "C" being the amount for the middle year of the series, "B" and "D" the amounts for the years next preceding and following, and "A" and "E" the amounts for the second year preceding and following respectively. In these formulae C′ is the progressive average for the middle year of each group used in constructing the smoothed curve, and by its use the accent on conditions peculiar to any one year may be avoided. Figure 7 is the curve plotted by the use of progressive averages obtained by Blandford's formula; in this formula the middle year of the

[1] See Beals, E. A.: Variations in Rainfall. Mo. Wea. Rev., vol. 39 (1911), pp. 1448–1452.

Fig. 7

Smoothed curve showing mean annual precipitation at Berkeley, California

five-year group receives six times the emphasis, and the years next preceding and next following the middle year receive four times the emphasis of the end years of the group. The result is a curve in which tendencies covering periods longer than a single year appear to be more clearly indicated than that in the curve of the annual rainfall. The curve obtained by the use of the other formula $\frac{B + C + D}{3} = C$, does not differ materially from figure 7, although it is not quite as smooth.

The smoothed curves for Berkeley do not cover a period long enough to show any progressive change in the precipitation as recorded by the gage measurements. Figure 7 does, however, show two distinct maxima during the period of the record, one in 1894–95 and the other in 1904–05. There is a suggestion of another maximum shortly before the beginning of the curve, which is, of course, the progressive average for 1889–90 two years after the beginning of the record. Two distinct minima are shown, one in 1891–92 and the other in 1897–98, another minimum is indicated about the end of the curve or a little later.

If there is any progressive change in the catch of the rain gage which would be the case were there a change in the amount of precipitation or any progressive sheltering of the gage, it would be shown by figure 7. It is evident from this figure that the period of the record is not of sufficient length to show with any degree of certainty that there has or has not been any such progressive change or long period oscillation in the rainfall at Berkeley since the beginning of the meteorological record in 1886. The curve does show an oscillation with a period of about ten years from crest to crest, but whether this is part of a cycle or merely an irregular variation does not yet appear.

SUMMARY AND CONCLUSION

The twenty-five year rainfall record for Berkeley shows the sub-tropical regime of precipitation. The greater part of the rain occurs between the beginning of November and the end of March, but rains are not uncommon except in July and August, which months are usually dry. The mean rainfall is 26.60 in.

(675.6 mm.) but the amounts for individual years show wide departures from the mean. In more than half the years the departure is small, less than fifteen per cent. The record fails to show any progressive change in the amount of precipitation. The Berkeley record is one of moderate length and has been kept under uniform conditions throughout the whole period; it may, therefore, be taken as characteristic of the rainfall relations for the eastern Bay Region.

UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY
Vol. 1, No. 3, pp. 81-126, pls. 12-20 April 4, 1914

PHYSIOGRAPHICALLY UNFINISHED ENTRANCES TO SAN FRANCISCO BAY

BY
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CONTENTS

INTRODUCTION

That the Golden Gate stands unique as the single deep-water passage through the westernmost ridge of the Coast Ranges of California is a fact which has long been emphasized in geographical literature. From the standpoint of the student of the influence of topography on man's movements, the importance of this opening in controlling the development of the state of California can hardly be overestimated. When considered, however, from the standpoint of the physiographic evolution of the Coast Ranges, the Golden Gate is seen to be merely that par-

ticular one of several openings through the mountains which happens to be at the special stage of development and at the particular hypsometric level necessary to admit tidewater freely to the interior valley now partially occupied by San Francisco Bay. There exist at least six other openings which might have been equally serviceable to man had the action of the erosional and diastrophic forces that control the evolution of topographic forms been varied but slightly in amount or in localization.

It should be borne in mind that the coast line of central California is mountainous, rising abruptly from the sea, frequently with slopes so precipitous that the only possible roadway along the coast is on top of the sea-cliff hundreds of feet above the water. Yet should the region around San Francisco Bay be uniformly depressed but 250 feet below its present level there would be not the single Golden Gate of today but six tidewater entrances to the bay, as may be seen in plate 12, on which the present bay is represented by the darker blue and the five new entrances which would result from the supposed subsidence by the lighter shade. A subsidence of an additional one hundred feet would connect San Francisco Bay with Monterey Bay through the valley of Coyote Creek, thus adding a seventh entrance and converting the Santa Cruz Mountains into an island.

As has been intimated, the physiographic interest in the facts to be presented here lies in the extreme ruggedness of the coast. The mountain ridge separating the bay from the ocean rises almost as abruptly from the one as it does from the other. This ruggedness suggests youthfulness or early maturity as the stage of the present topography in the geographic cycle, but some of the six passages through the ridge have characteristics belonging rather to late maturity or even to old age. Anticipating the descriptions to be given later, it may be postulated that in the vicinity of the bay a region well advanced toward old age in a former cycle has recently been subjected to diastrophic changes which have caused the development of much youthful topography without destroying many areas bearing features typical of maturity or of age. The six cross-valleys to be considered have quite different origins, and the purpose of this paper is to

describe the characteristics and to discuss the probable evolution of each of these, at present, physiographically unfinished entrances to San Francisco Bay.

General Physiography of the Valley of San Francisco Bay

San Francisco Bay has an area of about four hundred square miles, including the partially shut-off northern portion, which has the local name of San Pablo Bay. The axis of the bay as a whole conforms to the prevailing NW-SE trend of the Coast Ranges. The town of Petaluma is at the extreme northwesterly limit of tidewater; from that point the distance by way of Petaluma Creek, San Pablo Bay, and the main San Francisco Bay to the extreme southeasterly tidewater town of Alviso is nearly seventy miles. The Golden Gate is approximately midway between these two points. To the northwest of Petaluma the land rises gently to the fertile alluvial lands of Santa Rosa Valley and similarly beyond Alviso at the southeast is found the larger Santa Clara Valley. To the westward of the bay, the mountain ridge separating the valley from the ocean rises to over twenty-six hundred feet in Mount Tamalpais, ten miles northwest of the Golden Gate, while to the southward of the Golden Gate, opposite Santa Clara Valley, the Santa Cruz Mountains reach a height of over three thousand feet. Eastward of the bay, the ridges of the main Coast Ranges rise abruptly, the more distant peaks being higher than those on the west. Because of peculiarities of local surface drainage, the term Valley of the Bay of San Francisco is frequently restricted to the limits just indicated, but in reality the area described is merely the central depression of one of the three major longitudinal valleys of the Coast Ranges. While it is true that the northern and the southern ends of this larger valley are drained by rivers which do not empty into the bay, their basins are separated from the central depression merely by slight, almost imperceptible, elevations in the main valley floor, not by structural ridges. As topographic maps are not yet available for the major part of the Coast Ranges a photograph of a sketch model is reproduced in plate 13 to show the general topography of the

valley of the Bay of San Francisco. Local features are somewhat emphasized to represent the smaller passes on the scale of the model.

The relation of the main valley to the other valleys involves some consideration of the structure of the Coast Ranges. While their geological history is extremely complex, the present topography is relatively simple if considered only in its broader outlines. The Coast Ranges are generally described as a series of ridges roughly parallel both to the coast line and to the trend of the great interior valley of California. In more exact study it is recognized that the ridges not only vary slightly from parallelism, but that they frequently run together and coalesce. In consequence travel can not take place around the ends of the ridges, but must be over the intervening ranges in going from one valley to another. Passes, however short, transverse to the general NW–SE trend of the Coast Ranges are so unusual as to challenge investigation; in fact, for those familiar with the region the chief interest in the subject of this paper lies in the existence of so many cross-valleys in such a relatively short distance. The generalization asserting the parallelism of the ranges to the California Coast line must also be modified, the ridges of the Coast Ranges showing a marked, though by no means invariable tendency to cross obliquely from the Great Valley of the interior to the sea. In consequence of this direction of structural lines some of the valleys of the Coast Ranges open obliquely to the ocean. Of the three major valleys of the Coast Ranges two are of this type. The Salinas Valley in the southern half of the province heading against the western wall of the San Joaquin Valley opposite Bakersfield, opens to the coast at Monterey Bay. To the northward of San Francisco the Eel River has its headwaters on the westward slope of the range limiting the Sacramento Valley, and flowing obliquely across the Coast Ranges, empties into the ocean a few miles south of Eureka. Midway between these two valleys which open normally to the sea is the valley of the Bay of San Francisco, which has no structural outlet to the ocean, the Golden Gate being primarily an erosional opening. This valley is the longest within the Coast Ranges, but its three separate drainage systems and the various local names

of its sub-valleys have prevented the general popular recognition of its extent or even of its existence as essentially a unit depression. The extent of the valley from the head of the Russian River southeasterly through Santa Rosa Valley, San Francisco Bay and Santa Clara Valley to the source of the San Benito River is approximately 260 miles. The length of the entire valley is thus equivalent to that of the San Joaquin, but the alluvial floor is generally narrow, its extreme width of scarcely twenty miles occurring in Santa Clara County.

The waters of San Francisco Bay occupy the central and lowest part of this long valley, and it naturally would be expected that here should be the converging point for all the drainage, but the facts are not in accord with this supposition. The Russian River, as has elsewhere been described,[1] flows toward the bay for the greater part of its course, and then making an abrupt turn, cañons through the western highland to the ocean. It is a marked coincidence that to the southward the San Benito River, flowing northward toward the bay, also turns abruptly westward through a narrow gorge to the ocean. Because of the peculiar course of these rivers, the central portion of the valley of the Bay of San Francisco receives relatively little drainage from the Coast Ranges, but the major run-off of the state, the combined flow of the Sacramento and the San Joaquin river systems, enters the bay from the east by the gorge of Carquinez Straits, and leaves on the west through the Golden Gate—the submerged cañon which in a former cycle was the mouth of the Sacramento River.

In other words, the valley of the Bay of San Francisco is a long and narrow canoe-shaped depression, with the flood of the interior waters of the state pouring transversely across the middle through narrow breaks in the sides, while from either end of the canoe streams flow well toward the center, only to escape to the ocean through openings in the western rim, openings which are not in conformity with the present topography. Both of these openings are considered in this paper, as both offer low passes between valley and ocean.

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[1] Holway, R. S., "The Russian River, a characteristic stream of the California Coast Range," Univ. Calif. Publ. Geog., vol. 1, pp. 1–60, 1913.

The five openings which might function as additional entrances to San Francisco Bay, with a subsidence of only 250 feet, are Merced Valley, seven to eight miles south of the Golden Gate, Elk Valley, about four miles north of the Golden Gate, Lagoon Pass and Liberty Gap, the one just south and the other just north of Petaluma, already mentioned as the tidewater city at the northwestern extremity of the present bay, and most northern of all the gorge of the lower Russian River, opening westward from Santa Rosa Valley. The sixth valley, Pajaro Cañon, the gorge furnishing an outlet for San Benito River, needs a subsidence of over 350 feet to be filled by salt water.

In attempting to classify these cross-valleys by origin it is convenient to recall that theoretically they may be (1) either purely erosional, belonging to the present or inherited from a past geographical cycle, (2) purely constructional or diastrophic, or (3) erosional valleys developed along lines of structural weakness. Although the drainage of the Coast Ranges has usually been described as largely subsequent in nature, structural valleys following the same trend as the ranges have been recognized by geologists, but, so far as known to the writer, there is no record of a valley transverse to the trend of the Coast Ranges and primarily structural in development. Very probably there are cases where erosion along fault lines approximately transverse to the prevailingly NW-SE trend of structural lines accounts for existing valleys. The Golden Gate and Carquinez Strait may very possibly owe their exact location to such fault lines, the erosional valleys later developed having been drowned by relatively recent depression.

ELK VALLEY

Of the several valleys which a further submergence of this region to the extent of an additional two hundred and fifty feet would convert into entrances to San Francisco Bay the nearest to the Golden Gate is Elk Valley. In many ways it is the most striking of the cross-valleys to be considered. Located less than four miles to the northwest of the Golden Gate, its length of a little more than three miles is approximately the same as that of the valley which it roughly parallels in direction. Both

valleys are incised in rather rugged topography. Elk Valley may almost be termed a gorge, for on either side the hills rise to over a thousand feet in elevation within a mile. In the same distance from the Golden Gate an elevation of 960 feet is reached in a single peak on the north, while southward over two miles must be traversed before an elevation of 400 feet is attained. Even were the water withdrawn from the Golden Gate, the average elevations from the two valley floors would still be somewhat higher for Elk Valley than for the former. In slope, the northern wall of the Golden Gate is steeper than any portion of the sides of Elk Valley except its extreme westward end.

The topography between the two valleys is also greatly diversified. Midway in this small area the grade of a little streamlet flowing into Rodeo Lagoon is so low that its one hundred-foot contour is over a mile and a half from the sea, and yet on the rim of its basin five peaks slightly exceed or closely approach 1000 feet in height. To the northward, the western peak of Mount Tamalpais rises to 2604 feet within six miles of Elk Valley. In fact, marked relief is characteristic of the Coast Ranges for fully thirty miles from the Golden Gate. The Tamalpais highland, which has steep and almost precipitous slopes on both the southwest and the northeast, descends toward the northward to form the low belt extending from Santa Rosa Valley to the ocean near the mouth of Tomales Bay. The southern part of this highland ends abruptly, standing "knee deep" in San Francisco Bay, the water invading the valleys and converting the ridges into peninsulas and islands. The most western and most rugged of these peninsulas is the one cut by Elk Valley.

The present drainage of this valley should now be considered. Approximately midway from bay to ocean the valley floor rises to a height of 190 feet, forming a water-parting from which, during the rainy season, streams flow in opposite directions. Despite the fact that this divide exists midway in the valley floor, Elk Valley is essentially a unit, as can be seen in plate 14, where figure 1 shows the valley looking from the ocean toward the divide and figure 2 the view from the bay end. In both cases one sees beyond the 190-foot water-parting of the main valley bottom.

The valley as a whole seems to bear no genetic relationship to the little intermittent streams occupying its two halves. While with sufficient time they might have cut the lower portions of their valleys, there is no suggestion in the topography that these

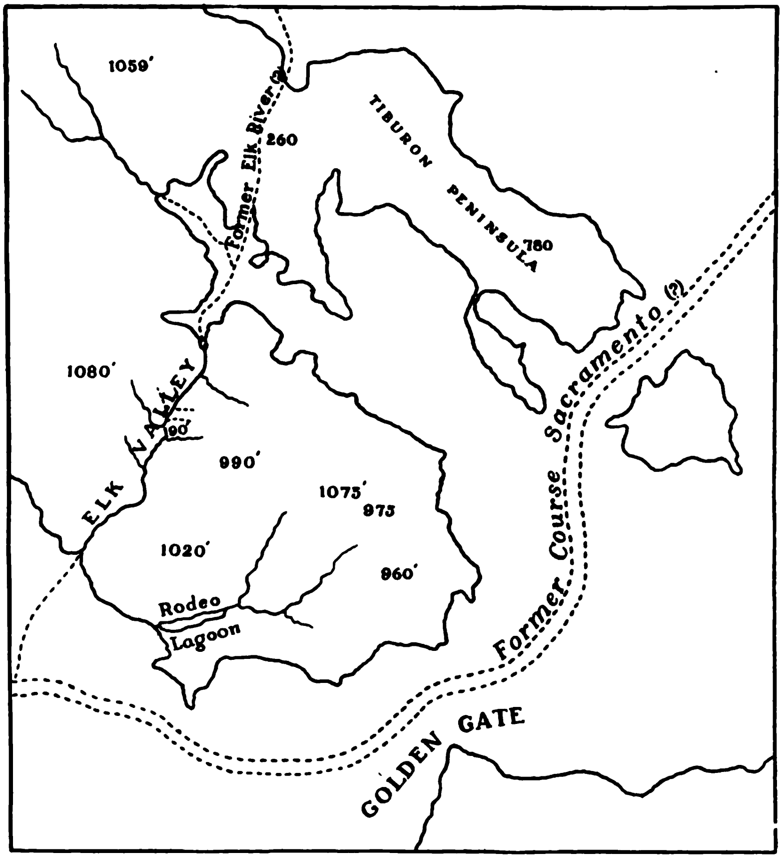

Figure 1

Sketch map showing peculiar drainage of Elk Valley. Dotted lines indicate the probable main drainage channels of a period preceding the faulting and subsidence which have established the present topography.

opposing streams could have lowered the divide between them and widened the resulting col to accordance with the rest of the valley. Other opposing streams both to the north and to the south have been unable to lower to any unusual extent the

crest line of the main ridge. In figure 1 is shown the drainage of Elk Valley as represented on the U. S. Topographic sheets—dotted lines being added to show the direction of side gorges not having streams of sufficient size to appear on the map. It will be noticed that the headwater rivulets of the two opposing streams of Elk Valley start on opposite sides of that gorge, and furthermore that these rivulets occupy ravines which open seaward into the main valley, as if both were tributaries to a west-flowing stream. The branch from the north on reaching the valley floor makes a turn away from the ocean of over 110 degrees and then flows northeastward to the bay; while the branch on the south bends but slightly to the southwest and continues to the ocean. The two streamlets pass within one-eighth of a mile of each other in the flat alluvial field in which lies the 190-foot divide at the center of Elk Valley. In the first half mile eastward of the divide the tributary gullies of the bay stream open oceanward as does the headwater ravine, and hence these small water-courses bend more than a right angle to flow toward the bay.

The suggestion is obvious that the entire Elk Valley is but part of the trunk of a former westward flowing river and that the present bay stream must have been reversed in direction by tilting. The uplift evidently was greater on the west, since the more youthful portion of Elk Valley today is at the mouth of the ocean-flowing stream. This is quite a general characteristic of streams in the northern coast ranges,[2] and will be considered further in connection with some of the other passes to be described.

Naturally the question arises whether any other traces may be found of the old river supposed to have formed Elk Valley. Seaward the extensive deposits of the tidal delta of the Golden Gate have made impossible the detection of any submerged valleys, had they ever existed. However, the possibility certainly exists that Elk Valley is a fragment of a tributary of the Sacramento when the land stood higher and the mouth of that river was some distance westward, nearer the edge of the continental shelf. To the landward Elk Valley opens into the tidal marshes

[2] Lawson, A. C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, p. 252–3, 1895; Fairbanks, H. W., Bull. Am. Bureau Geog., vol. 2, p. 351, 1901.

and drowned inlets of the bay. Crossing this depressed area and bearing somewhat more to the northward there is found a low gap of 260 feet across Tiburon Peninsula—a gap separating elevations of from 500 to 700 feet from the still greater heights on the slopes of Mount Tamalpais. In the absence of definite signs of the old stream-courses it can only be said that the elevations make this a probable extension of the former river.

In conclusion it may be stated that Elk Valley is an erosional opening through the western ridge of the Coast Ranges, and that it is evidently a portion of the trench of an old stream cut off from the remainder by the diastrophic movements which brought the present bay into existence.

LAGOON PASS

Lagoon Pass crosses the northern edge of the Mount Tamalpais highland and is the longest of the low valleys connecting the bay with the ocean.[8] Its entire length following the meanders is fully twenty-five miles from salt water to salt water. In genesis the pass is most closely related to Elk Valley, the shortest of these entrances, for, like the latter, it has undoubtedly developed from the trench of a river belonging to a former geographic cycle.

The bay entrance to the valley begins at the mouth of San Antonio Creek, which empties into Petaluma Creek about six miles southeast of Petaluma. Going westerly up this stream some twelve miles, the divide between bay and ocean is found crossing from left to right the valley floor shown in plate 15, figure 1. Just before reaching this divide and at practically the same level the head of San Antonio Creek is found in a shallow lagoon which is generally dry during the summer. Just beyond the divide in a little side valley to the north there is a larger lagoon from which the water flows westward to the Pacific in a stream called Walker Creek. The field between the two lagoons, in which lies the water-parting, is so nearly level that

[8] Lagoon Pass really opens into Tomales Bay instead of directly into the ocean. As "the bay" in this paper usually means San Francisco Bay, the western end of the valley of Lagoon Pass will be spoken of as the ocean end, to avoid the confusion which might result to readers not familiar with local names.

according to the reports of residents the rivulets of the rainy season flow toward the bay or toward the ocean, according to the irregularities of the last plowing. An examination of this field between the lagoons shows that it is a flat alluvial fan built out by a little tributary from the south toward the northern wall of the pass and leaving a slight linear depression from which during heavy rains water flows both to the ocean and to the bay, thus affording free passage for those species of fish which run to the headwaters of streams. The elevation of the alluvial flat between the lagoons is 225 feet, as determined by aneroid barometer—a very low height when it is considered that the distance either westward to the ocean or eastward to the bay is about twelve miles.

The topography bordering this twenty-five mile valley reveals something of its past history. The hilltops near the lagoons range in elevation from five hundred feet on one side to a thousand feet on the other, the height of the Tamalpais highland falling rapidly toward the northward in this vicinity. The character of the valley throughout its course varies in a striking way. The middle portion is mature—the rather narrow flat at the divide in plate 15, figure 1 widening greatly either eastward or westward. At both bay and ocean the valley ends in gorges of very youthful aspect. The western end, lower Walker Creek, is cut to sea-level in a rather even-topped highland ranging from 400 to 800 feet in elevation. The steep sides of Walker Creek descend from grain fields having in general a gentle rolling topography with an occasional higher knoll. An area well advanced in an erosion cycle apparently has been uplifted long enough for the main stream to reach base level, but not long enough for it to widen its channel materially. A narrow flood-plain extending two or three miles from salt water is very plainly not due to lateral corrasion of the stream, but to aggradation resulting from slight recent subsidence.

Lower Walker Creek, although deeply entrenched in a highland, has very pronounced meanders, a rather common characteristic of streams in this vicinity. As stated elsewhere in discussing the Russian River,[4] the hypothesis that these entrenched

[4] Univ. Calif. Publ. Geog., vol. 1, pp. 27–28, 1913.

meanders are derived from the meanders of a stream in a base-leveled plain seems a satisfactory one, but should not be regarded as necessary in all cases. In Walker Creek we have apparently an ideal illustration of a stream meandering on the seaward border of an old peneplain later becoming entrenched without displacement during uplift. In this case the uplift is apparently the tilting of a block, the westward edge fronting the San Andreas Fault, along which horizontal movement took place in 1906. In plate 15, figure 2, is shown a view rather typical of lower Walker Creek in the last six or seven miles of its course. The flattened end of the spur in the foreground is somewhat exceptional, but there is other evidence in nearby sea terraces indicating that this portion of the Coast Ranges was uplifted not continuously, but by a series of movements, although they are not commonly registered in small streams. In the flat hilltop in the left of the view is given a suggestion of the mature highland in which the gorge is cut. The photographs reproduced in plate 16 will help one to visualize the topography. Both views are within a mile of the mouth of Walker Creek, the gorge of which crosses the middle distance from right to left about six hundred feet below the grain fields in figure 1, while figure 2 shows the gorge itself, the line of sight being at right angles to that of the previous view and the grain fields of the former being found on the flat top of the ridge in the left of the latter view.

Turning now to the eastern half of the valley of Lagoon Pass, San Antonio Creek, as has been already stated, is also very youthful in its lower course. At the mouth its gorge is cut in hills which rise abruptly six hundred feet above the tidal flats of Petaluma Creek. In general the topography adjacent to San Antonio Creek should probably be characterized as a dissected highland, although it is more varied in relief than that around Walker Creek. Speaking in terms of the assumed previous peneplanation of this region, the portion around Walker Creek must have been more nearly reduced to base-level than that adjacent to San Antonio. In plate 17, figure 1, the view is taken looking downstream from a point two or three miles below the head of San Antonio Creek. With no other knowledge than that gained by observation from this viewpoint, the conclusion would be war-

ranted that the view was taken looking upstream rather than downstream. In fact, going eastward from the viewpoint the flat portions of the floor actually do rise for some distance, San Antonio Creek flowing in "anaclinal" style against the slope of the old valley floor in a trench incised below its level. In plate 17, figure 2, is shown a view looking across the valley floor, showing in the foreground the present San Antonio Valley sloping to the bay, while above may be seen fragments of a graded surface sloping to the right, or westward, to the ocean. The preceding description has been couched in terms which have already suggested the writer's hypothesis as to the genesis of

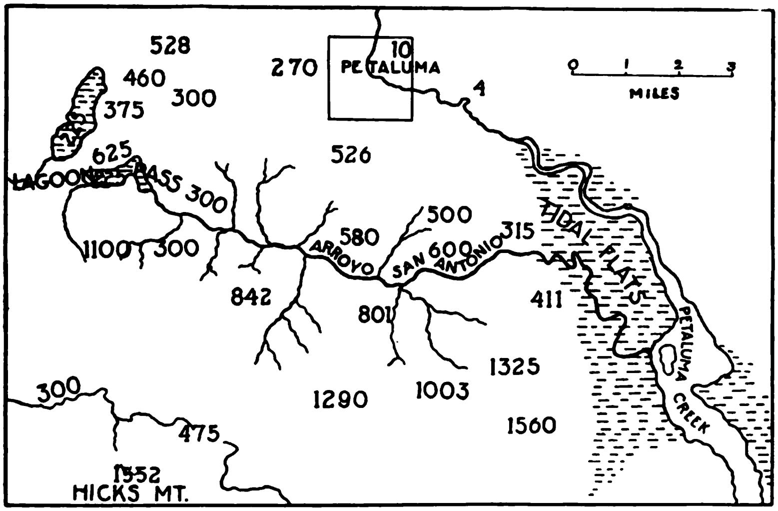

Figure 2

Sketch map showing drainage pattern of San Antonio Creek—the eastward-flowing stream of Lagoon Pass. Elevations and drainage from the advance sheets of the Petaluma quadrangle furnished by the courtesy of the Director of the United States Geological Survey.

the valley. An old westward-flowing stream seems to have headed somewhat to the eastward of the lagoons near the present divide. The topography near the bay shows in the reconnaisance work so far done no remnants of the trunk channel of a former stream, but some westward-pointing tributaries (see fig. 2) have been

found which ultimately flow to the bay, indicating reversed drainage similar to that in Elk Valley. The mouth of San Antonio Creek is, then, a new gorge developed during, and as the result of, recent diastrophic changes. The process by which this was done does not seem entirely clear. From the Golden Gate to Petaluma the Mount Tamalpais highland meets the bay in a fairly bold front, with slopes so steep in most places as to suggest recent folding or faulting. The areal geology of this region is not yet published and there is no reliable map for the details of drainage. In the present state of the investigation the hypothesis which accords best with the known facts may be stated as follows: In the movements following a former period of partial base-leveling a block reaching from near the present Petaluma Creek to the San Antonio fault near the ocean was slowly uplifted, the greater uplift being on the west. The old westward-flowing river extending nearly the full length of this block persisted, the rejuvenated stream cutting near the ocean the youthful gorge of the present Walker Creek. In the middle portions of the old river the grade was lessened and the river even ponded near the present lagoons, causing sedimentation. In the meantime on the extreme edge of the block some small stream rejuvenated by uplift rapidly pushed its divide westward by headward erosion; rapidly, for in competition there was the sluggish headwater portion of the old river ponded by tilting toward the bay. Under these circumstances the bay stream pushed westward its headwater gully, finding in the trench of the old west-flowing river its best location. Meanwhile near the lagoons ponding had produced such extensive sedimentation that portions of the flood-plains finally established by the old west-flowing river still remain, although the drainage is now eastward to the bay. The hypothesis may be said to involve the formation of a syncline in the old erosion surface near the present lagoons.

The outcropping rocks in the vicinity belong to an old series (Franciscan) upon which the later rocks of the Coast Ranges have been deposited, and have been so much folded and faulted that there is no possibility of getting any stratigraphic evidence of recent folding. To the northeastward Santa Rosa Valley is

a synclinal fold in late rocks, according to Osmont,[5] who has also shown in a section fifteen miles to the northwest of the lagoons a syncline, the axis of which, if it follows the prevailing structural trend of the Coast Ranges, would pass through the lagoons. This strengthens the topographic evidence of depression afforded by the recent sedimentation in the vicinity—sedimentation for which it is otherwise difficult to account. According to the foregoing, Lagoon Pass, in spite of its much greater length, is to be classed with Elk Valley in genesis as being developed from a valley inherited from a former geographic cycle.

LIBERTY GAP

The next opening from the bay valley to the ocean is about six miles north of Lagoon Pass and over thirty miles from the Golden Gate. Liberty Gap, naming it from the schoolhouse near the water-parting, is genetically different from the two passes already considered. It is not a narrow opening cut below the adjacent levels, but is the broad, low belt already mentioned, made by the downward pitching of the general level of the Tamalpais highland. The topography has the slight relief and gentle slopes of age (pl. 18, fig. 1). The low hills, seldom more than four hundred feet above the sea, are monadnocks, the harder rocks frequently outcropping. The region is evidently a portion of an old erosion surface lying approximately at the level at which it developed and presumably forms part of the old peneplain, fragments of which various writers on the physiography of the state have noted at elevations ranging from one thousand to four thousand feet or even more. The portion here described is exceptional in being so nearly at its original level of peneplanation. Northward the old surface rises again and, traced by the general accordance in level of the flat tops of the hills, it can be carried across the gorge of the lower Russian River to the highlands of the Mendocino Plateau. Southward in like manner the old surface is carried on the hilltops bordering Lagoon Pass and traces of it are found around Mount Tamalpais. To the east of Liberty Gap the old surface is presumably found below

[5] Osmont, Vance C., Univ. Calif. Publ. Bull. Dept. Geol., vol. 4, pl. 7, 1905.

the alluvial deposits of Santa Rosa Valley and to the southeast monadnock-like hills project in places out of the marshes borbering Petaluma Creek. Still farther to the southeast across shallow San Pablo Bay there are many indications that the old surface may again be identified in the lowlands bordering the San Francisco Bay along the northern extension of the Berkeley Hills.

Returning to the specific question of a low-lying connection between the bay valley and the ocean, the water-parting between the two is found on this old surface quite close to Santa Rosa Valley. The lowest point in Liberty Gap is about six miles northwest of Petaluma, where the elevation is but 150 feet, checking the aneroid barometer by readings on known stations along the nearby Petaluma and Santa Rosa Railroad. While the water flows from this point westward some twelve miles to the ocean, the general level of the old erosion surface rises, reaching its greatest height close to the seashore. Here are some of the largest areas of quite flat land, the low plateau ending abruptly at levels some six to seven hundred feet above the sea. In this plateau the west-flowing streams have cut narrow cañons which, like the cañon of Lower Walker Creek, have been modified by the accident of slight recent subsidence. In this vicinity the lower portions of the channels are still narrow lagoons not yet filled by sediment. In plate 18, figure 2, the view was taken between two and three miles from the ocean, looking westward at the Estero San Antonio, one branch of which heads at the 150-foot point in Liberty Gap. The narrow lagoon is largely tidal water. The meanders are similar to those described in Walnut Creek, but are not so deeply incised. The hills in the distant center are near the ocean and have quite extensive flat fields not visible from the low viewpoint. The next creek northward shows a similar but larger lagoon at its mouth. Both small streams are extreme instances of the abnormality mentioned as common to coast streams in this region, namely, in having youthful valleys at their mouths and older forms toward their headwaters. Both have their headwaters to the eastward in the old topography near the low divide on the border of Santa Rosa Valley and both have their widest valley floors and most gentle slopes in their

middle courses. A typical view is given in figure 19, plate 1, which is taken almost exactly half way from divide to ocean, looking across the valley opening into the Estero San Antonio. The lowest level in the center of the valley at the left is under one hundred feet. The bare outcrop on the right and the gentle slopes of the distant hills, which probably are less than three hundred feet in elevation, are characteristic of the low belt of Liberty Gap.

Some interesting topography bearing on the physiographic development of the region westward of both Lagoon Pass and Liberty Gap is shown in plate 19, figure 2. In the foreground is seen the flat aggraded floor of a little tributary which enters Walker Creek near its mouth. This valley floor where the cattle are now grazing was formerly the tidewater port for the little town of Tomales, the scattered houses seen in the distance being part of that village. Tomales about 1860 developed into a farming center, shipping potatoes to the young city of San Francisco. The inlet then, at least at high tide, had enough water for schooners and for a small steamer to bring lighters from the deep water. The harbor was given up about 1875 because of the building of the railroad and because the cultivation of the former grass-covered slopes had resulted in rapid erosion and in correspondingly rapid deposition, which has now converted the former harbor into a meadow. The topography in figure 2 is also interesting because it shows how the elevation of the old surface seen around Walker Creek in figure 2, plate 15, becomes rapidly lower in going northward from Lagoon Pass toward the region westward of Liberty Gap.

Briefly summarizing, that the special importance of Liberty Gap in the present paper may not be lost in the related physiographic detail, this particular potential entrance to the valley of San Francisco Bay owes its existence to two facts: First, it is situated on a low-lying portion of the old peneplain of the Coast Ranges, and secondly, it is connected with the ocean by the incised gorges of streams which have persisted against the landward tilting of a block, the uplifted edge of which is at the present coast line.

RUSSIAN RIVER GORGE

The most northern of the entrances to San Francisco Bay which would result from the supposed further depression is the gorge through which the Russian River flows in the last twenty miles of its course. The writer has recently discussed this stream in considerable detail,[6] and only the briefest resume of the portion concerning the gorge will be made here as an introduction to a consideration of its relation to the other cross-valleys described.

The lower Russian River is the remnant of an old consequent stream which existed at the close of the period of peneplanation in the Coast Ranges. Slow uplift has deeply entrenched this portion of the river, but the region to the eastward has had a long history of depression, deposition and changes of level which have resulted today in the low-lying alluvial Santa Rosa Valley to the northward of the present San Francisco Bay. As said in the introduction, the Russian River flows southeasterly from the northwestern end of the canoe-shaped valley of the bay of San Francisco, until it reaches the portion locally called the Santa Rosa Valley, and then, although there is no ridge separating it from the waters of the bay, it turns westward, flowing through twenty miles of gorge to the ocean. The height of the indefinite water-parting between the river and the bay reaches its maximum of 113 feet in the grain fields ten miles to the northward of Petaluma. A subsidence of 250 feet would thus extend the bay northward over Santa Rosa Valley beyond the town of Healdsburg and make the gorge of the Russian River a salt-water estuary 200 feet and more in depth, with over 130 feet for the shallowest water between it and the present bay. The Russian River entrance to the enlarged San Francisco Bay is, then, in genetic history similar to that commonly accepted for the Golden Gate, the difference being that the Russian River is a small stream, while the Sacramento River, the old mouth of which has become the Golden Gate, is the major river of the state.

Of all the potential entrances to the bay Russian River Gorge and Liberty Gap have the lowest divides separating them from the present level of the bay. Liberty Gap in particular is also

[6] Univ. Calif. Publ. Geog., vol. 1, pp. 1–60, 1913.

in a region of lower general relief than that bordering the Golden Gate and is no more distant than is the latter from Carquinez Strait, through which the Sacramento reaches the bay valley. Considering these relations, the question why the present entrance is cut close to Mount Tamalpais at the Golden Gate rather than through the open country near Liberty Gap invites speculation. The presumption is that, when the bay region was at its lowest state of degradation in the previous geographic cycle, the course of the Sacramento was fixed, its mouth being at the present Golden Gate and that subsequent uplift was so slow that the river uninterruptedly maintained its course. If elevation had been faster for a period than the downward cutting of the river, ponding would have resulted, with overflow through the lowest available channel to the ocean. So long as ponding did not take place, if other possible openings were separated from the river by divides barely above the highest floods, the persistence of the course through the Golden Gate was as well assured by low barriers as by mountain ridges.

This speculation as to the rather simple factors controlling the course of a river during uplift is offered not only as part of the discussion of the problems of this paper, but also in connection with the past discussion as to the former outlet of the Sacramento having been southward through Santa Clara Valley into Monterey Bay—an hypothesis which will be considered further in the description of Pajaro Cañon.

MERCED VALLEY

The two remaining valleys of the six enumerated for discussion lie to the southward of the Golden Gate and both have been discussed in geological literature, but not from the standpoint of this paper. Professor Lawson named Merced Valley and included it in his general description of the topography of San Francisco Peninsula.[7]

Merced Valley is from seven to ten miles south of the Golden Gate and is entirely distinct in character from the other valleys described. They have a direction roughly at right angles to the

[7] Sketch of the Geology of San Francisco Peninsula, 15th An. Rep. 1893–94, U. S. G. S., pp. 405–476.

trend of prevailing structural lines and in origin are primarily erosional. Merced Valley extends NW-SE in harmony with the trend of the main ridges and valleys of the coast and in origin is structural. Its southwestern slope carries recent marine deposits which are folded down beneath the valley floor and abut against the uplifted fault block of San Bruno Mountains on the northeast. Figure 1 of plate 20 is a view looking down on a model of San Francisco Peninsula, and shows Merced Valley extending northwesterly from the bay to the ocean, a distance of some eight miles. The highest point in the pass is about 190 feet. Both ends of the valley are occupied by intermittent streams and both bear topographic evidence of recent submergence. Although structurally Merced Valley would seem to be a natural outlet for Santa Clara and San Benito valleys, there is no evidence that it has ever functioned as a drainage channel for their waters during the present geographic cycle.

PAJARO CAÑON

In the geological literature of the past this cañon has figured, not as an unfinished entrance to San Francisco Bay, but rather as a discarded outlet for its waters. Professor Joseph LeConte advanced the theory that the Sacramento River formerly flowed southward through the valley of the bay of San Francisco to Pajaro Cañon and thence to Monterey Bay.[8] His basal assumption postulates an elevation of the land during Pliocene time of some 2000 to 2500 feet more than at present, with the shore line consequently much farther to the west and the river valleys correspondingly extended on the continental shelf. He then argues that, as there is no submarine valley off the Golden Gate and as there is a well-defined one in Monterey Bay, the Sacramento must have flowed southward in the valley of the bay of San Francisco and thence to Monterey Bay. That is, he considers the Golden Gate a recent opening which has been made by an uplift shutting the Sacramento off from its first outlet into Monterey Bay. He gives no consideration to the probability that any submerged channel off the Golden Gate would have been fully obliterated by the extensive deposits of the tidal delta since

[8] Bull. Geol. Soc. Am., vol. 2 (1891), p. 326.

formed, nor to the probability that with the land at a higher elevation than the present the combined drainage of the Salinas and San Benito rivers might be fully competent to cut the submerged cañon found in Monterey Bay. These two considerations, together with the further fact that the narrow Pajaro Cañon shows no signs of having been occupied by a river the size of the Sacramento, seem to the writer to render extremely improbable the theory advanced by Professor LeConte—a theory for which he himself states the main object "is to direct attention and stimulate investigation." Other objections to Professor LeConte's theory, based on the height of the present divide between San Francisco and Monterey bays compared to the heights of the divides between San Francisco Bay and the ocean, have recently been considered[9] by Professor J. C. Branner of Stanford University, although he does not mention the three passes which lie to the north of Elk Valley. Dr. Branner calls attention to the fact that the water-parting separating the present San Francisco Bay from Monterey Bay is 345 feet instead of less than one hundred feet, as quoted by Professor LeConte, and that with the higher elevation the closing of the Golden Gate would cause overflow to the ocean at other low places before the water would escape southward through Pajaro Cañon. This is evident *provided the elevations in the past had the same relative height as in the present.* The latter proviso seems very doubtful if the topography has evolved according to Professor LeConte's theory, which is based on the supposition that an orogenic depression of over two thousand feet has taken place since the period he fixes for the drainage of the Sacramento through Pajaro Cañon. In a general change of two thousand feet elevation for the bay region as a whole it is very probable that the relative elevations of passes and ridges were greatly changed.

The writer is in entire agreement with Dr. Branner's conclusion that "the theory of the postglacial age of the Golden Gate does not appear tenable," although the opinion is based upon somewhat different considerations. The broader conclusion offered from the results of the present investigation is that there

[9] The Drainage of Santa Clara Valley, Jour. of Geology, vol. 15 (1907), pp. 1–10.

is no physiographic evidence that any of the six openings in addition to the Golden Gate between the valley of the Bay of San Francisco and the ocean have ever functioned as outlets for the Sacramento River during the present geographic cycle, extending that period sufficiently to include the faulting and folding since the last marked peneplanation. Pajaro Cañon in this paper takes its place as an opening which with uniform depression of over 345 feet would for the first time afford a salt-water connection from the present San Francisco Bay to the ocean. Genetically it seems to be the southern correlative of the Russian River in its relation to the valley of the Bay of San Francisco. Its gorge is shorter and does not maintain its rugged character clear to seacoast. The longest tributary of Pajaro River is the San Benito, which, although differently named, probably should be considered the trunk stream. The San Benito-Pajaro drainage basin has many problems which invite detailed study.

PHYSIOGRAPHIC CHANGES AND FAUNAL RELATIONSHIPS

The diastrophic changes which have led to the development of the present topography in the bay region have evidently resulted in many accidents to the drainage systems occupying that area. These changes are not to be thought of as necessarily belonging to a remote past. The writer has described the transfer of a tributary of the Russian River to the Sacramento drainage by a landslide so recent that its form and its track are still plainly recognizable.[10] In this portion of the Pacific Coast there is not lacking evidence that folding and faulting may even now be causing slow changes in level sufficiently great to affect delicately adjusted drainage systems. In addition it is well accepted that ordinary processes of stream erosion or of deposition may make changes in the boundaries of drainage systems. Reversing of streams and transference of tributaries must be now and must in the past have been likely to be accompanied by changes in the fluvial faunas of the region. Some notes on the connection between physiographic changes and faunal problems in the Coast Region have already been published. The change in the Russian

[10] Science, N. S., vol. 26 (1907), p. 382.

River drainage referred to above has been commented on by Professor Snyder of the Department of Zoology of Stanford University, who has pronounced the physiographic change in the instance reported as immaterial to the biologist because the Sacramento River has a larger fauna which includes the strictly fluvial species of the Russian River, and that hence any number of changes in that direction would produce no changes in faunal groups. The present study has added some knowledge of drainage changes and drainage connections in the central Coast Ranges of California which seem to bear on faunal relationship. To show the possible importance of these changes there is added the following brief statement of some of the problems in this vicinity from the standpoint of the biologist.

Notes on Faunal Problems of Russian River and Tributaries of Tomales and San Pablo Bays, by Professor J. O. Snyder, Department of Zoology, Stanford University.*

The fish fauna of the Russian River is much like that of the Sacramento-San Joaquin system, differing mainly in that it lacks some species that are found there. Besides anadromous forms like the lamprey, *Entosphenus tridentatus*, the trout, *Salmo irideus*, and some other species that are able to poss freely from salt to fresh water as the stickleback, *Gasterosteus cataphractus*, the cottoids or bullheads, *Cottus gulosus*, *C. asper*, and *C. aleuticus*, there are now known to inhabit the Russian River four strictly fluvial species, a sucker, *Catostomus occidentalis*, and three minnows, *Mylopharodon conocephalus*, *Ptychocheilus grandis* and *Rutilus symmetricus*. Only the latter, the strictly fluvial fishes, should be considered in a discussion of the faunal relationships of rivers, for being unable to withstand salt water, they must remain in a system when once they are introduced, their position being analogous to that of reptiles on an oceanic island. These four species of their closely related representatives are of very restricted distribution, occurring only in the Sacramento-San Joaquin system, and in certain coastal streams of central California. All inhabit the larger tributaries of San Francisco Bay. *Catostomus*, *Ptychocheilus*, and *Rutilus* are represented in the streams which enter Monterey Bay, but no farther south, and *Rutilus* occurs in Gualala and Navarro rivers which reach the ocean at points north of the mouth of Russian River. *Catostomus humboldtianus* of Bear, Eel and Mad rivers is apparently a representive of *C. occidentalis* of the Russian and Sacramento rivers. Some of these characteristically Sacramento species have also found their way into the streams that flow into Tomales Bay.

Large series of specimens of these fluvial species from both the Russian and Sacramento rivers, and also from the streams tributary to San

* Private communication to the writer.

Francisco Bay were at one time carefully examined in an attempt to determine whether any slight differences in structure or color might be found between them. None appeared, the fishes differing only as individuals of a species from a given stream might differ among themselves, except in the case of *Rutilus symmetricus*, a small silvery minnow, where a slight amount of differentiation seemed evident. Individuals from Russian River appeared to be slightly more slender, with somewhat longer fins, the whole body being of more trim and elegant proportions. When specimens from Russian River and from Gualala and Navarro rivers were compared it became quite evident that certain small, but measurable differences existed, those from the latter streams having more robust bodies, deeper caudal peduncles, and more rounded and shorter snouts.

To recapitulate: the fauna of the Russian River is essentially that of the Sacramento-San Joaquin in so far as the latter is represented, a slight amount of differentiation possibly appearing. One Russian River species is represented in Gualala and Navarro rivers to the northward, where a marked degree of differentiation has appeared.

When therefore one considers the relationships of the species, and the relative geographic positions of the streams, one is warranted in concluding that the Russian River fauna was derived from the Sacramento-San Joaquin system.

There is another matter of considerable interest in connection with the Russian River and Sacramento fishes. I have stated that the representation of Sacramento-San Joaquin fishes is not complete in the Russian River. There are lacking certain species, *Orthodon microlepidotus*, *Lavinia exilicauda*, *Pogonichthys macrolepidotus* and others, which are abundantly able to maintain themselves in smaller streams, e.g., those tributary to San Francisco Bay. Why are not these found in Russian River? Possibly an answer will present itself when one comes to consider the means by which Sacramento fishes might have reached the Russian River. However, if one finds that at one time the two streams had a main channel connection, I can see no way to account for the absence of these species. If, on the other hand, it becomes apparent that the Russian River received its fauna by some method of stream capture by which only a small part of the upper course of a creek was diverted, there then appears to be an opportunity for a reasonable explanation. For *Orthodon*, *Lavinia*, and *Pogonichthys* are channel fishes, inhabiting the lower courses of the rivers, preferring the deeper and more quiet waters, while *Catostomus*, *Rutilus*, and *Ptychocheilus* closely follow the trout to the headwaters. If my observations on their habits are not at fault it will appear that the chances of the latter fishes for a migration through an upstream connection are much better than those of the channel forms, and if an opportunity were presented for such a migration, or if a small part of a tributary were transferred to another system, the upstream fishes would be more likely to profit by it.

Regarding the fishes of the streams tributary to Tomales Bay: I have found but two fluvial species there, a sucker, *Catostomus occidentalis*, and a minnow, *Rutilus symmetricus*. A detailed examination of many well-preserved specimens of these species and comparisons with specimens

from the Sacramento-San Joaquin river system reveals no important differences. Similarly it was found that no differences appeared when fishes of the Tomales Bay streams were compared with those of Russian River. In so far as they have been observed, the fishes of the tributaries of Tomales Bay are like those of the streams flowing into San Pablo and Suisun bays.

The streams tributary to Tomales Bay are very small, and with the exception of Paper Mill Creek, where both *Catostomus* and *Rutilus* may always be seen, they do not offer very favorable opportunities for the existence of river fishes.

Might it not be possible that an ancient connection occurred between the Sacramento and the Russian River basins, one so long ago that all superficial evidences have disappeared, that a little later a passageway was opened for migration from the Russian River to the Navarro, which was also obliterated, and then more recently fishes were again introduced from the Sacramento at various times and in sufficient numbers to swamp any variation that might have set in among the Russian River fishes? That would account for differentiation in the Navarro, for only one species occurring there, and for the lack of differentiation in Russian River.

While physiographic study in the region covered by Professor Snyder's notes cannot be said to have advanced much beyond the reconnaissance stage as yet, the results already obtained concerning connections, past and present, between the different drainage basins come surprisingly close to the conditions which he has theoretically outlined as solving the biological problems. These results will now be summarized for the three areas mentioned.

RELATION OF RUSSIAN RIVER TO BAY DRAINAGE

The question of present and past connections between the Russian River and the Sacramento River and other streams flowing into the northern portion of San Francisco Bay is quite complex because of the extensive area involved. Assuming, as seems reasonable, that the marsh lands around the northern end of the bay become covered with fresh water during extensive floods from the Sacramento and that consequently strictly fluvial species from that river may reach the streams from Santa Rosa and from Sonoma Valleys, there are two instances where physiographic conditions seem to meet exactly the conditions laid down by Professor Snyder as affording "opportunity for a reasonable

explanation." The first locality is on the western slope of Sonoma Mountain facing Santa Rosa Valley, where the indefinite divide in the valley floor separates Petaluma Creek from Copeland Creek, a tributary of the Russian River. Copeland Creek heads well up on Sonoma Mountain and has built quite an extensive low-grade fan at the point where it debouches upon the valley floor. The fan is noticeably convex to the eye where it is crossed by the county road leading north to Santa Rosa. From the apex of the fan channels lead northward to the Russian River and also southward to San Pablo Bay—channels which when recently visited were separated by a low ridge less than two feet high. Nearby residents assured the writer that in flood time the stream frequently discharged southward to the bay. The conditions for the prevention of the mingling of channel fish "preferring the deeper and more quiet waters" and for permitting passage to the upstream fish from the bay to Russian River seem to meet the requirements set by Professor Snyder.

Sonoma Mountain lies between the alluvial floors of Santa Rosa and Sonoma Valleys. The second opportunity for the mingling of upstream fishes was found in the latter valley. In going northward from San Pablo Bay, Sonoma Valley, instead of narrowing in the conventional way to gorges and ravines lost in encircling hills, gradually changes the slope of its alluvial floor at an elevation of 464 feet just above the railway station at Kenwood, descends toward the northwest, and connects with Santa Rosa Valley. At the highest point in the valley an alluvial fan has been built out a distance of a little over a mile (plate 20, figure 2). The fan is formed by a stream from Hood Mountain on the east. In this case migration of the stream has apparently not occurred within the period of some fifty years since the valley was settled. There is, however, a small channel on the north side leading to Russian River, while the main flow at present is southward to the bay. The latter channel is incised some twelve feet, and a flat slope less than a hundred feet wide separates it from the small northern channel. The fan is occupied as a farm, the apex being well covered with farm buildings and cultivation may have obliterated older channels. From the known habit of streams in building fans it is practically certain

that so long as the fan was being built the stream flowed alternately toward the Russian River and toward San Pablo Bay. That period may be far back historically but it is probably recent compared to time needed for species to change perceptibly.

RELATION OF TOMALES AND SAN PABLO BAYS

The second of the problems referred to by Professor Snyder is at least partially answered by the description already given of Lagoon Pass. Duck-hunters vouch for the fact that the streams flowing east and west from the central divide of that valley are frequently united by standing water joining the two headwater lagoons. In the present topography there does not seem to be opportunity for free intermingling of the various streams flowing into Tomales Bay, as there is no continuous marsh land surrounding it. The bay is, however, very shallow, its twenty-five miles of length affording only one spot where the water is sixty feet in depth. Remembering that Tomales Bay lies along and is undoubtedly causally related to the San Andreas fault zone, it may well be that in comparatively recent times the elevation has been such as to exclude salt water and to unite the tributaries of the bay into one trunk stream. The present connection of Walker Creek and San Antonio Creek is well established, and the possible extension of the connection to all the streams of Tomales Bay by relatively slight changes of level will be granted.

The more detailed study of the migration of streams on alluvial fans and the effect of uplift and depression in uniting coast streams or dismembering drainage systems in their relation to fresh-water fauna has not been attempted because of the excellent discussion of the same problem by Doctor Branner for the streams of Santa Clara Valley and Pajaro River in the paper referred to above.

RELATION OF NAVARRO TO RUSSIAN RIVER

Referring to Professor Snyder's remarks on the fauna of the Navarro River in comparison with that of the Russian and Sacramento rivers, the recent physiographic study of the Rus-

sian River[11] already cited indicates a past history remarkably similar to that outlined in his hypothetical question as to the possible physiographic changes which might account for faunal conditions (page 105). The past relations of the Russian and Navarro rivers may be briefly summarized as follows: the Navarro River formerly headed considerably to the eastward of the course of the upper portion of the present Russian River. The notably linear southeast course of the upper Russian River is held to be the work of a subsequent stream which has developed headward along a line of weakness and has successively beheaded various coast streams of the Mendocino Plateau, among others the Navarro. The capture is indicated by the eastern tributaries of this portion of the Russian River flowing northwesterly to join that stream instead of southwesterly as they normally should, and by remnants of the trench of the former Navarro. The period at which this capture occurred is certainly far back in the past and may be sufficiently remote to account for the differentiation of species transferred from the Russian to the Navarro at that time. Previous connection of the Russian and Sacramento drainage may well have been established before the capture, considering the conditions of peneplanation indicated in the study of Liberty Gap. Connection in recent times between the latter rivers seems to be proven beyond a doubt so far as headwater connections passable for upstream fishes are concerned. These later conditions would apparently explain the lack of differentiation today in the fauna of the Russian and Sacramento basins.

[11] Univ. Calif. Publ. Geog., vol. 1, pp. 11–13, 1913.

SUMMARY

Including the Golden Gate with the six valleys discussed, they may be classified as follows:

Primarily Developed by Erosional Forces

A. Russian River Gorge, Golden Gate, Pajaron Cañon	Gorges of tne lower courses of rivers which have maintained themselves during uplift. The recent depression drowning the Golden Gate has affected the other two but to a less extent.
B. Lagoon Pass, Elk Valley	Remnants of the trenches of old streams which have not maintained their courses during uplift—modified by subsequent erosion of present streams.
C. Liberty Gap—	A low-lying remnant of an old erosion surface. Streams have since cut gorges to the ocean through the uplifted western edge.

Primarily Developed by Diastrophic Forces.

A. Merced Valley—	A structural valley having the prevailing trend of other structural features of the region.

Only one of these valleys is now occupied by salt water. The other six are here grouped together because their low elevation makes possible their becoming entrances to an enlarged San Francisco Bay in the event of subsidence of the region during future geological time. The unstudied and topographically unmapped region to the north of Mount Tamalpais may contain other low-lying passes at an elevation not far from that of the divide at present separating San Francisco Bay from Pajaro Cañon.

So far as the facts have yet been determined in the two branches of science carrying on the preliminary investigations, the present and past physiographic relations seem to harmonize reasonably well with the faunal relationships of the fluvial species belonging to the drainage basins in the region of the northern portion of the valley of the Bay of San Francisco.

Transmitted July 25, 1913.

PLATE 12

SAN FRANCISCO BAY AND VICINITY

The lighter blue shows the five additional entrances and the enlargement of San Francisco Bay which would result from a subsidence of the land two hundred and fifty feet below the present level. Boundaries of submerged areas are diagrammatically correct merely.

PLATE 13

Central Coast Ranges of California

The sketch model represented on this plate is thought to be correct to the extent of giving a reasonably accurate impression of the general features of the central coast region of California. No reliable topographic maps exist for the major portion of the area shown. The exact elevation of the mountains of the extreme northern portion is known in relatively few instances; elevations south of the Golden Gate are fairly accurate.

PLATE 14

Elk Valley

Figure 1. Looking northwestward up the western portion of Elk Valley toward the divide which runs transversely across the valley floor in the extreme distance.

Figure 2. The bay portion of the pass, looking southwesterly toward the same divide. Both views fail to include the full height of the hills bordering the pass.

PLATE 15

Lagoon Pass

Figure 1. The flat valley floor in the view is the indefinite divide from which the water flows westward to the ocean and eastward to the bay. A low-grade alluvial cone built out from the left toward the hills on the right (the north) leaves a slight depression which during heavy rains drains both westward and eastward.

Figure 2. Ten miles westward from the divide in figure 1 above, Walker Creek, the western branch of Lagoon Pass becomes the narrow, youthful gorge shown in the lower view of the plate. The very flat top of the hill in the upper left-hand corner of the picture is characteristic of all the hilltops of the vicinity.

PLATE 16

Walker Creek Branch of Lagoon Pass

Figure 1. Old erosion surface, elevation six to eight hundred feet, in which the gorge at the mouth of Walker Creek is cut.

Figure 2. The gorge of Walker Creek which crosses from right to left the middle distance of the view above. The flat, graded floor of the gorge is due to sedimentation following recent subsidence.

PLATE 17

San Antonio Branch of Lagoon Pass

Figure 1. A view taken looking downstream in the valley of San Antonio Creek. The topography is that usually characterizing views taken looking toward the headwaters of a stream.

Figure 2. A view southward across the San Antonio.

The present valley floor slopes to the eastward (the left in the photograph), while above are portions of the former valley floor sloping westward.

PLATE 18

LIBERTY GAP

Figure 1. The divide separating bay from ocean is marked approximately by the row of trees on the skyline. The elevation of one hundred and fifty feet for the lowest part of the crestline in Liberty Gap was taken in the larger opening in the trees. The knoll in the central foreground is a monadnock of harder rock.

Figure 2. Estero San Antonio, the creek heading against the low divide shown above, when it nears the ocean cuts a gorge through the hills shown in the distance in this view. These hills are really quite flat-topped and front the ocean with an escarpment three hundred to four hundred feet high.

PLATE 19

Figure 1. Old topography characteristic of the middle and upper course of the Estero San Antonio which flows westward from Liberty Gap.

Figure 2. Meadow in the alluvial floor of a little tributary to Walker Creek. This tributary was the harbor for Tomales until 1875.

UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY

Vol. 1, No. 4, pp. 127-240, pls. 21-28 February 19, 1914

THE RAINFALL OF CALIFORNIA

BY
ALEXANDER G. McADIE

CONTENTS

ACKNOWLEDGMENTS

The data used in preparing this memoir are essentially the official records of the United States Weather Bureau, with which the writer has been connected for many years. The records for California extend for some localities over a period of sixty-three years. Through the labors of disinterested and faithful observers like Dr. G. H. Gibbons, Dr. T. M. Logan, Thomas Tennent, John Pettee, Samuel Gerrish, Dr. Hatch, Mr. H. D. Vail and many others in different parts of the state, complete long-period and strictly comparable records of temperature and rainfall are available for study of seasonal rainfall distribution. Originally a three-inch gauge of the type known as the Tennent gauge was in general use. The Southern Pacific Company installed this gauge at a large number of stations and for many years maintained an efficient system of reports. In 1871 the official records began with the establishment of a United States Signal Service office in the old Merchants Exchange Building, San Francisco. Records were also maintained under the auspices of the Smithsonian Institution at various points, also at military posts by army surgeons and by the Lighthouse Board. The writer had in his possession in the vaults of the Weather Bureau office the original records of Dr. Gibbons, Dr. Logan, and correspondence from John Bidwell relating to weather conditions previous to 1849. These and other records were unfortunately destroyed by the San Francisco fire of April 18, 1906.

It may be noted that when the missions were flourishing records were kept of rainfall in connection with crop yields. Doubtless some of these records will yet be recovered and translated. At the present time only fragmentary data are available.

The early Spanish explorers noted weather conditions with some detail and in the narratives of the expeditions of Cabrillo, 1542, Viscaino, 1602, Anza, Portola, Fages, Serra and others are many comments on the rains, wind and fog. Francis Drake in 1579 anchored a few miles northwest of San Francisco in what is now called Drakes Bay, and in the narrative of the voyage given by Francis Fletcher there is much detail regarding the climate. Professor George Davidson, for nearly fifty years a student of early exploration on the Coast, has in various papers identified the anchorages and voyages of these explorers, and to him we are indebted for translations and abstracts of logs.

In 1887 the *San Francisco Chronicle* generously distributed rain gauges to about fifty localities in the state. With the co-operation of the Signal Service these were installed by Mr. H. E. Wilkinson. For a short period the State Agricultural Society with headquarters at Sacramento, with the co-operation of the Signal Service, Mr. James Barwick acting as compiler, published monthly and annual bulletins. This work was taken over in 1896 by the California Section of the Climate and Crop Service of the Weather Bureau, which subsequently was merged in District 11, *Monthly Weather Review.*

Since 1895 the compilation of rainfall records in California has been under the direct supervision of the writer, excepting for a period of a few months in 1898–99.

He desires to express his obligations to the many gentlemen throughout the state who volunteered their services in recording rainfall, also to the various officials of the Weather Bureau, particularly Mr. George H. Willson; and to Professor R. S. Holway and Mr. W. G. Reed of the University of California for suggestions and help.

CHIEF FACTORS CONTROLLING RAINFALL

The rainfall of California is determined essentially by five factors:

A. The location and intensity of pressure areas known as continental and oceanic highs and lows. The oceanic low of winter is generally known as the Aleutian low. These permanent pres-

sure areas have been called centers of action; and more recently hyperbars and infrabars, the former when pressure is in excess of the normal and the latter when the pressure is below a normal value.

B. The prevailing drift of the surface air from west to east in temperate latitudes.

C. The proximity of the Pacific Ocean, a great natural conservator of heat, the mean annual temperature of which near the coast ranges from 10° C to 16° C, 50° F to 61° F.

D. The diversified topography of the state.

E. Ocean currents, especially those contiguous to the coast.

CENTERS OF ACTION: HYPERBARS AND INFRABARS

The pressure distribution determines the general character of the season, i.e., the prevailing movements of the surface winds, the mean temperatures and the amount and frequency of rain. In various papers[1] published in recent years attention has been called to the relation between pressure distribution and the character of the season. In the *Climatology of California,* page 7, a general law is given that:

> "Typical wet winters on the California coast occur when the North Pacific low overlies the continent west of a line drawn from Calgary to San Francisco. Typical dry winters are associated with a westward extension of the continental high to the coast line and a retreat of the Aleutian low to the northwest."

In a normal season the Aleutian low extends from latitude 40° N to 60° N and from longitude 130° W to 140° E.

In summer months the distribution of pressure changes. The Aleutian low practically disappears. The continental high is displaced somewhat eastward, and the oceanic high moves farther north. Summer in California is practically rainless, and there are strong west and northwest winds.

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[1] McAdie, A. G., "Climatology of California," U. S. Weather Bureau Bulletin L, 1903; Fassig, O. L., Amer. Journ. Sci., November, 1899; Lockyer, W. J. S., Science Progress, October, 1906, no. 2; Okada, T., Central Meteorological Observatory Bulletin no. 4, Tokyo, Japan, 1910; Humphreys, W. J., "Origin of the Permanent Ocean Highs," U. S. Weather Bureau, October, 1911; McAdie, A. G., "Forecasting the Water Supply in California," Monthly Weather Review, July, 1913, also Bulletin Mount Weather Observatory, December, 1910, and Monthly Weather Review, April, 1908.

The accompanying charts show the pressure distribution during selected dry and wet weather months. Figure 1 shows the sea-level pressure and surface winds during January, 1902, typical of a dry winter month. Other dry winter months were January, 1898 and 1904, February, 1899, 1890, and 1912, March, 1898, 1901, and 1908.

Fig. 1

Typical pressure distribution and wind during a dry winter month. The hyperbar, 1024 millibars (30.25 inches) favoring north winds over California.

Figure 2 shows the sea-level pressure and surface winds during February, 1902, typical of a wet winter month. Other wet winter months were January, 1906, 1907, 1909, 1911, February, 1904 and 1909, March, 1904, 1907, and 1911. For examples see plates 23 and 24.

Plate 25 shows the precipitation during January, 1902, a dry winter month. The deficiency in water supply was approximately 33,000,000 acre feet. Plate 26 shows the precipitation during February, 1902, an abnormally wet month. The excess of water supply amounted to approximately 43,000,000 acre feet.

Fig. 2

Typical pressure distribution and wind during a wet winter month. The infrabar 1007 millibars (29.75 inches), favoring south winds over California.

It is also to be pointed out that the frequency and path of individual disturbances depend primarily upon the strength and location of the larger areas. Individual lows move rapidly southward when the continental high overlies Idaho, eastern Washington and eastern Oregon. Similarly when the Aleutian low extends well southward, individual lows deepen rapidly and move south rapidly. Under such conditions the rain area will extend from the Washington coast to the northern California coast in twelve hours, to the central coast in twenty-four hours, and to the coast south of Point Conception in thirty-six hours.

Prevailing Surface Drift

Under the second head, B, the prevailing drift of the atmosphere from west to east, we have a general explanation of the strong westerly winds prevailing on the California coast. The charts of wind direction issued each month for the North Pacific show in detail the frequency and intensity of the wind for all parts of the coast. From the 55th parallel to the 30th the winds are chiefly northwest. In summer between latitudes 35° N and 40° N winds are distributed as follows: West to northwest, 75 per cent; north to northeast, 4 per cent; east to southeast, 3 per cent; south to southwest, 3 per cent; and calms, 15 per cent. In winter the winds are southeasterly, and southerly gales are frequent. Nevertheless, northwest winds are not infrequent, as is shown by the following: West to northwest, 30 per cent; north to northeast, 18 per cent; east to southeast, 17 per cent; south to southwest, 22 per cent; and calms, 13 per cent.

It is because of the general motion of the air from west to east that the climate of west coasts is less severe than the climate of east coasts. If the circulation of surface air were reversed, the Atlantic Coast and the middle portion of the country would have their temperature extremes much reduced and the climate would be in many respects milder than that which now exists. On the other hand, the climate of the Pacific Coast, and especially of California west of the Sierra, would lose much of its present equability. The winters would be rigorous and the summers very warm. Plate 27 shows the surface air movement over the Pacific Ocean in winter and in summer.

Ocean Effect

Under the third head, C, proximity of the Pacific Ocean, it is to be noted that owing to the high specific heat of water the oceans are the great natural conservators of heat. The mean annual temperature of the Pacific near the California coast is 13° C, 55° F. The prevailing winds therefore blow over a surface that is warmer in winter and cooler in summer than a land surface would be. The temperature amplitude of all the coast stations is therefore small compared with that of the interior.

During the summer months the mean temperature of the water is about 15° C, 60° F. The diurnal change in the temperature of the water is small. During the winter the mean temperature of the water is about 10° C, or 50° F. Interesting comparisons

Fig. 3

Annual average isobars (solid lines), isotherms of air (dotted lines), cold ocean currents (smooth arrows), warm ocean currents (wavy arrows).

Modified from Origin of the Permanent Ocean Highs by W. J. Humphreys, U. S. Weather Bureau Ocean Meteorological Chart, October, 1911, also Bulletin, Mount Weather Observatory, vol. 4, part 1.

of water-surface temperatures, air temperatures and currents may be found in the ocean charts issued by the United States Weather Bureau each month. One point, however, should be noted in connection with the air temperature at sea, and that is that observations are made close to the water surface and do not represent the air conditions at a height of several hundred feet.

TOPOGRAPHY

Under D, the diversified topography of the state, we have perhaps the most important factor in determining local climates. The state has a mean length of nearly eight hundred miles and an average width of two hundred miles. Its area is 155,908 square miles, or a little less than a hundred million acres. The coast line corresponds in position with that portion of the Atlantic Coast extending from Boston to Savannah. There are very few rivers, and in both orography and hydrography there is little resemblance to the Atlantic seaboard. The coast line has a mean annual temperature ranging from 10° C, 50° F to 15° C, 60° F, while on the Atlantic Coast the temperature ranges from 8° C, 47° F to 20° C, 68° F. In July the isotherms run almost north and south on the Pacific Coast, while on the Atlantic Coast they conform to the parallels of latitude. In the winter the difference between the mean temperature of the interior of California and the coast amounts only to about 3° C, 5° F, but in the summer the difference is marked, amounting in general to 11° C, 20° F.

Orography plays an important part in controlling the movement of the surface air (see fig. 4, illustrating the diversified topography of the state). The prevailing westerly winds, wherever allowed access to the interior through gaps in the Coast Range, modify and practically control the temperature. On the other hand, when the movement of the surface air is from the north or northeast, there are marked foehn effects due to the passage of the air over the mountains and thence down into the valleys. One of the most trying climatic features of California is the so-called "norther" or hot wind, caused by dynamic com-

In all these cases the air has been dynamically heated and dried in its passage from the Great Basin southwest or south over the Sierra and thence down the western or southern slopes. The velocity of the wind sometimes exceeds ten meters a second, twenty miles an hour, and as much dust is carried the conditions created are generally disagreeable.

During December and January under certain pressure distributions there are well-marked foehn effects in the counties south of the Tehachapi. Afternoon temperatures will exceed 27° C, 80° F. Morning temperatures, however, are low, owing to intense radiation.

We thus have the same pressure distribution resulting in cool nights and warm afternoons.

Ocean Currents

Temperature anomalies on the Pacific Coast have been in past years explained as due to the effect of the Kuroshiwo or Japan current; but the explanation is far from being conclusive and the effect of the current has been greatly exaggerated. Some recent hydrographic investigations made by McEwen at the Scripps Institution for Biological Research, of the University of California, at La Jolla, testing Ekman's theory of oceanic circulation and the phenomena of upwelling waters along the continental margins of the great oceans, make it clear that the low summer temperature of the sea from Point Conception south is due to other causes than the California branch of the Japan current.

The principal currents in the North Pacific are the north equatorial, the equatorial counter-current, the Kuroshiwo, the California current, and the Behring Sea current. The north equatorial flows west in the region of the trade winds and reaching the islands off the Asiatic coast is deflected north. The equatorial counter-current flows eastward a little north of the equator. The Kuroshiwo is a portion of the north equatorial current, passing north of Formosa and southeast of Japan. Leaving the Japanese coast, the current becomes more of a drift, fanning out and flowing eastward past the Aleutian Islands,

dividing into north and south drifts on the Alaska coast. The California current is that portion of the Kuroshiwo flowing southeast some distance from the Oregon-California coast. Between this current and the shore is a narrow counter-current known as the Davidson current, flowing north. (See pl. 28.)

The California current is colder off the California coast than the water of the Pacific farther west. There may be some relation between this difference of temperature and the fog.

McEwen on Upwelling Cold Water[2]

Numerous observations extending over a long period have established the presence of abnormally cold surface water contiguous to the west coast of North America, and various conflicting theories have been proposed to account for the phenomenon.

The conclusions reached by different investigators may be summarized as follows:

1. A cold Arctic current flows south along the coast from the polar regions.

2. The Japan current, because of its passage through high latitudes, becomes cooled, and as it flows south along the coast of the United States appears as a cold stream because its temperature corresponds to the normal value prevailing in higher latitudes.

3. The accumulation of water in the south polar region causes an excess of pressure which drives the cold bottom water northward with an increasing velocity owing to the diminishing distance across the Pacific, till when it reaches the latitude of Sitka, Alaska, owing to the deflecting force due to the earth's rotation, it is driven up the continental slope and flows south as a cold current, since it has no other outlet.

4. The coldest water is located about 1200 kilometers, eight hundred miles, south of Sitka in the summer time, and areas of

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[2] McEwen, Geo. F., "The Distribution of Ocean Temperatures Along the West Coast of North America Deduced from Ekman's Theory of the Upwelling of Cold Water from the Adjacent Ocean Depths," Internationale Revue der gesamten Hydrobiologie und Hydrographie, Band 5, Heft 2 und 3 (1912), pp. 243–286, 21 text figures, 4 tables. See also Monthly Weather Review, December, 1912.

alternately warm and cold water are distributed in an irregular manner all along the coast. But from each of the previous theories, owing to the continual increase in the heating effect of the sun toward the south, a continuous rise in temperature would accompany a decrease of latitude. Therefore the low temperature must result from an upwelling of cold bottom water from the adjacent ocean depths. A general eastward drift of the ocean water extending to the bottom is assumed to result from the continued action of the winds; consequently the cold bottom water is driven up the continental slope, most of it reaching the surface at Cape Mendocino (the coldest region). The irregularities in temperature distribution are due to the effects of submarine valleys and differences in the slope of the ocean bottom.

The above theories were based on hypothetical causes, which in some cases were not verified except by the general qualitative agreement of the deductions with the particular observations considered.

Before going on with the conclusions regarding the Pacific Coast region it will be necessary to consider general theories of oceanic circulation. A recent one due to Ekman differs from that of Zöppritz in that no assumption as to regular flow in plane layers is used as a basis, but a virtual value of the coefficient of viscosity allowing for the actual turbulent motion of the water, is used, and the deflecting force due to the earth's rotation is also introduced. Many results of Zöppritz's theory are inconsistent with observations, while those of Ekman's theory are in harmony with experience. Most of the results of the two theories are entirely different.

From Ekman's theory it follows that there must be an upwelling of the cold bottom water along most of the coast of North America owing to the action of the observed winds, and in the present paper, assuming the low temperature to be due entirely to cold bottom water upwelling and mixing with the surface water, a theoretical formula was derived by which the abnormally low temperatures of any region could be computed for each month of the year. A very satisfactory agreement with observations was obtained, though the temperature reduction below the normal varied from 0° to 8° C.

The following table, showing the data used and the results obtained for a belt of water extending west from San Francisco, indicates the agreement between the theoretical and observed temperatures. The formula derived for this region is $T = (1 - 0.030\ V_w)t_2 + 0.030\ V_w t_1$, in which

T is the surface temperature of the inshore water;

t_2 is the normal surface temperature for the latitude;

t_1 equals 8° C, the mean temperature of the upwelling water;

V_w is the component of the average wind velocity in miles per hour parallel to the coast line over an area whose center is about four hundred kilometers from the coast. All of the variable quantities correspond to the same month.

Month	V_w	t_2 °C	Calculated T. °C	Observed T. °C	Differences °C
1	7.70	14.20	12.80	12.50	- 0.30
2	6.87	13.80	12.60	11.60	1.00
3	9.25	12.60	11.30	11.50	—0.20
4	11.40	12.00	10.60	11.30	—0.70
5	12.50	14.50	12.10	11.30	0.80
6	14.40	15.20	12.10	13.80	—1.70
7	17.50	20.00	13.70	13.50	0.20
8	18.60	19.90	13.25	13.00	0.25
9	17.60	19.90	13.60	13.80	—0.20
10	13.60	18.10	14.30	14.60	—0.30
11	8.80	16.60	14.30	13.90	0.50
12	6.65	15.20	13.80	13.40	0.40

In general the theory shows that the area affected and the magnitude of the temperature reduction and its distribution vary with the depth of the water, the slope of the bottom, the velocity of the winds, the portion of the surface over which they extend, and their steadiness.

To give an idea of the pecularities of temperature distribution that have been accounted for by means of these principles, the following results of observation are enumerated:

The cooling effect of the upwelling water extends to a distance of six hundred kilometers from the coast off Cape Mendocino, latitude 40°, and increases to a distance of 2100 kilometers from the shore off San Diego, latitude 32° 45′.

The temperature reduction in the summer is a minimum off San Diego and a maximum off Cape Mendocino, where the coldest surface water is found.

Temperatures as low as 14° C in August have been found in certain limited areas near the coast south of latitude 35°, while the value 18° C prevailed in the surrounding water a few miles away, both north and south.

Considering the complexity of the phenomena, the agreement between the theory and the observations has been very satisfactory, and judging from the results already obtained it would be profitable to carry on a more detailed and quantitative investigation following the lines suggested in the present paper.

STATE DIVISIONS

For convenience in discussing the data, the state has been divided into five sections, bearing some relation to the principal watersheds. These divisions are:

Northwestern California;

Northeastern California;

Central California;

California south of the Tehachapi;

California east of the Sierra.

Northwestern California

This includes the coast counties north of the bay of San Francisco, also the Coast Range counties west of the Sacramento watershed. Beginning with Del Norte and the western half of Siskiyou counties, the district extends south, including Humboldt, Trinity, Mendocino, Lake, Sonoma, Napa, and Marin counties. The four last named constitute a sub-division, known locally as the Bay Counties. There are four small valleys in this subdivision known as the Russian River, Sonoma, Napa, and Vaca.

The Coast Range runs north and south through the entire district and climatic conditions vary greatly within short distances, owing to the diversified topography.

The coast line is bold and rugged. There are many projecting headlands, the best known of which is Cape Mendocino, latitude 40° 30′ N. The well-known Point Reyes, latitude 38° 11′ N, longitude 122° 51′ W, is formed by a westward projection with a hook to the south, thus making an open roadstead, known as Drakes Bay. Francis Drake anchored here in June, 1579.

There are few harbors in the 290 nautical miles.[3] The following table gives the distance in nautical miles of the chief headlands:

	Km.	Miles
San Francisco to Point Reyes	53	33
Point Reyes to Point Arena	108	67
Point Arena to Cape Mendocino	158	98
Cape Mendocino to Eureka	37	23
Cape Mendocino to Point St. George	126	78

The Coast Range extends in a nearly north and south line the entire length of the district. The St. Helena Range is the best known of the several minor ranges. Mount St. Helena, elevation 1402 meters, 4600 feet, is situated at the intersection of Napa, Lake, and Sonoma counties. In the northern portion of the district there are many peaks exceeding 1800 meters. The range is locally known as the Trinity Mountains. Farther west are the smaller ranges known as the Scott Mountains, Salmon Alps; and to the southwest the South Fork Mountains and Elk Ridge. The Siskiyou Mountains of Oregon extend southward into California.

The various ranges mentioned form watersheds for numerous small rivers. The streams of the eastern slope of the Coast Range drain into the Sacramento. In the north the Klamath River, and its tributary, the Trinity, drain the four northwestern counties, emptying into the Pacific Ocean. The Eel River drains the Mendocino and Lake sections, flowing northwestward.

There are comparatively few lakes in this section, the only one of any size being Clear Lake, in the center of Lake County.

The most noticeable climatic features of the coast district are the moderate temperatures, the frequent fogs and the high winds.

[3] A nautical mile is a minute of an average great circle. It is 800 feet (244 meters) more than a statute mile.

The climate of the interior, i.e., of the valleys back from the coast, is entirely different, as will be shown later. Few extreme temperatures are recorded, the highest temperature at Eureka being 29.6° C, 85.2° F, on June 6, 1903, and the lowest, —6.7° C, 20° F, January 14, 1888. A good idea of the small temperature range is obtained from the statement that the mean of the maximum temperatures for a period of ten years at Eureka was 14° C, 57° F, and the mean of the minimum temperatures, 9° C, 47° F. The evenness of temperature is due to two factors, viz., the proximity of the ocean, and the prevailing movement of the air in these latitudes from the ocean to the land.

The winds are, as stated above, generally west, but during the winter months, owing to the approach of barometric depressions from the north, high southeast winds occur. These winter storms, known locally as "southeasters," are the most important climatic features of this section. Heavy rains accompany these storms. During the summer months there are but few disturbances. The west winds, however, in the summer months blow steadily during the afternoon hours. Occasionally during the months of April, May, and June these west or northwest winds reach high velocities. In a paper entitled "Some High Wind Records on the Pacific Coast," in the *Monthly Weather Review*, February, 1908, McAdie and Thomas give records covering high velocities obtained with northwest and southeast winds. On February 25, 1902, at Point Reyes, for two hours the velocity varied from 40 to 45 meters a second, 90 to 100 miles an hour, with an extreme velocity of 46 meters a second, 103 miles an hour, or a mile in thirty-five seconds. Again, on March 1, during a severe southeast gale there is a record of one mile in a little less than thirty seconds; and for five minutes, including the time of the extreme velocity, the miles average less than thirty-four seconds, or at the rate of 48 meters a second, 107 miles an hour. From May 15 to 20, 1902, high northwest winds prevailed along the entire coast. At Point Reyes Light, for the forty-eight hours ending midnight, May 18, the average velocity of the wind was 32 meters a second, 72 miles an hour. For the last twenty-four hours of this period the average velocity was 35 meters a second, 78 miles an hour, for the last twelve hours, 84 miles, and for the

last six hours, 88 miles. The greatest wind movement recorded in any one hour was 164 kilometers, 102 miles. The maximum velocity for the storm was 49 meters a second, 110 miles an hour, at 8:50 P.M., May 18, and the extreme velocity 120 miles, at 8:38 P.M. The record of the whole period is complete and legible, and of the 7565 kilometers, 4701 miles, shown, only 27 kilometers, 17 miles, are interpolated, owing to the fact that the anemometer cups were carried away and this interval elapsed before a new set of cups could be put in place. The feat was performed by Mr. W. W. Thomas at a time when the wind was blowing at the rate of 41 meters a second, 91 miles per hour.

The writer has found a reference on the old forecast charts at San Francisco to a record of 48 meters a second, 108 miles an hour, from the southeast at Cape Mendocino, on January 22, 1886, at 7 A.M. There was also a note that a maximum velocity of 64 meters a second, 144 miles an hour, from the southeast occurred at Cape Mendocino, on January 20, 1886.

In the paper referred to above can be found wind records for San Francisco, Point Lobos, Mount Tamalpais, Point Reyes, and a number of interesting accounts of the velocities experienced at sea by masters of various steamships and sailing vessels.

The month of May is as a rule the month of maximum air movements. A good illustration of the duration and strength of this northwest wind is afforded by the following table, showing velocities during May, 1903:

WIND MOVEMENT FOR MONTH

Stations in California	Total for month		Average daily		Greatest hourly movement		Greatest in 24 hours	
	Km.	Miles	Km.	Miles	Km.	Miles	Km.	Miles
Point Reyes Light	38,740	24,072	1,249	776	2,692	1,673	142	88
Mount Tamalpais	27,151	16,871	875	544	1,913	1,189	126	78
San Francisco	16,157	10,040	521	324	832	517	55	34
Point Lobos	24,834	15,431	801	498	1,495	929	97	60
Southeast Farallon	27,892	17,331	900	559	1,907	1,185	93	58

A distinctive feature of the coast climate is the sea fog. The fog belt extends along the entire coast. During summer afternoons the depth of the fog stratum varies from 30 to 518 meters, 100 to 1700 feet. Frequently the lower level of the fog stratum

is 30 meters, 100 feet, or less above the sea or ground surface. Experiments in the vicinity of Mount Tamalpais indicate an average summer afternoon temperature of 27° C, 81° F, for the levels 2300 feet, 700 meters, and above. At saturation this would equal 25,486 grams per thousand cubic meters, 11,275 grains per thousand cubic feet. The temperature at sea-level is about 13° C, 55° F. At saturation this would equal 11,249 grams per thousand cubic meters or 4849 grains per thousand cubic feet. The condition is therefore entirely different from some of the well-known fog formations on the Atlantic Coast, where warm water supplies the necessary vapor, and fogs form when the north or northwest winds of lower temperature than the water favor condensation.[4] Kite experiments indicate that at the 1000-meter, 3280-foot, level on summer afternoons there is a moderately strong flow of air from east to west. It would seem as if the heated air of the great valley, or some portion of it, moved seaward above the level of the incoming or east flow of the surface draught.

The climate of the counties back from the coast is, as previously stated, entirely different from the coast climate. These inland valleys are sheltered from the ocean winds and show a marked difference in temperature amplitude, and in humidity. While on summer afternoons the coast sections are cool and foggy, the interior sections are warm, dry, and with little wind stirring unless the wind is from the north, in which case it may be strong. A fair idea of the climate of the interior may be obtained from the records of the station at Upper Lake, kept by Mr. Charles Mifflin Hammond, co-operative observer, for a period of more than twenty-five years. A temperature of 43° C, 109° F, has been recorded once, July 31, 1909, and temperatures of 41° C, 105° F, several times during the midsummer months. The lowest temperature ever recorded was —9° C, 16° F, on December 18, 1908. The following table prepared by Mr. Hammond shows the greatest daily range in a given year:

[4] There are, of course, other fog formations where warm south winds blow over cool water surfaces.

UPPER LAKE

Month	Times above 32° C 90° F	Times below 0° C 32° F	Greatest daily range ° C	Greatest daily range ° F
January	0	14	22	40
February	0	2	17	31
March	0	5	21	37
April	0	0	22	40
May	0	0	24	44
June	6	0	26	47
July	24	0	30	54
August	22	0	31	56
September	14	1	31	56
October	1	14	30	54
November	0	9	27	48
December	0	12	24	43
Year	67	57	31	56

Humboldt Bay, the most northern port of California, is the most important harbor between San Francisco Bay and the mouth of the Columbia River. Eureka is the largest city on the northern coast. A detailed description of the climatology of Eureka by Mr. A. H. Bell of the Weather Bureau can be found on pages 25 to 33 of Bulletin L, "Climatology of California." Mr. Bell says:

From October until April is the rainy season, but the wet period is by no means a season of continuous precipitation. Sometimes a rainy season will include much pleasant weather. While the prevailing winds are in summer northerly, seldom indeed do they attain the velocity of a gale, usually rising before noon and subsiding before nightfall. These winds are extremely liable to ensue on two or three consecutive days. In winter, on the other hand, the prevailing winds are southeasterly.

Humboldt Bay has a varying width of from half a mile to four miles and a length of fourteen miles. It lies nearly parallel with the coast and between it and the ocean there intervenes a sand peninsula, with a width of from one-fourth mile to one and a half miles. So narrow is the entrance and so peculiar are its relations to the body of water within—in other words, so completely landlocked is our harbor—that tempestuous weather outside affects it very little.

Northeastern California

This section includes the northeastern counties, lying east of an imaginary line through the foothill section of the Coast Range and south to a line drawn from the northern side of San Francisco Bay to Lake Tahoe. The counties in the district are Solano.

Yolo, Sacramento, Placer, Nevada, Sutter, Colusa, Butte, Sierra, Plumas, Lassen, Shasta, Modoc, and the eastern portion of Siskiyou, Tehama, and Glenn. Practically it is the watershed of the Sacramento River and its tributaries. This is the principal river of California. The following note relating to the hydrography of the section is taken from a publication of the Weather Bureau, "Climatology Data of the United States by Sections," Bulletin W, Section 15:

The portion of the drainage basin above Red Bluff, California, extends from the Trinity Mountains on the west to the Warner Mountains, near the California-Nevada state line, on the east. The watershed on the west from the Trinity Mountains is comparatively narrow, being only from ten to thirty-five miles in width, and furnishes a very small portion of the discharge of this river; but from the east, Pit River, which is the most important tributary, drains a large area extending about 120 miles east from the Sacramento River between Mount Shasta on the north and Lassen Peak on the south. The greater portion of this basin is composed of lava and shows other evidence of volcanic activity, such as volcanic cones and craters. Nearly all the streams tributary to Pit River have their origin in large springs, many of which discharge several hundred second-feet. The most important tributary of the Pit is McCloud River, draining the southeastern slope of Mount Shasta. It derives its waters principally from the melting of the snow on the high elevations of this mountain. The western portion of the watershed extending along the Trinity Range is well timbered, as is also that portion of the drainage area in the Sierra Nevada lying between Mount Shasta and Lassen Peak. Farther east, however, there is little or no forest covering, and the country is used extensively for pasturage.

The most prominent mountain in the section, and indeed one of the highest and most imposing peaks in the United States, is Mount Shasta, elevation 4349 meters, 14,380 feet. The writer succeeded in carrying two mercurial barometers to the summit of Mount Shasta on August 5, 1905, and obtained from a series of six readings a mean pressure of 457.0 millimeters, 17.99 inches. Simultaneous readings at sea-level were made and the resulting height of 4298 meters, 14,200 feet, computed. The boiling point at the summit was 86.5° C, 187.7° F. This would mean an equivalent pressure of 459.2 millimeters, 18.08 inches. The height of Shasta, as given on the U. S. Geological Survey sheet, is 14,380 feet (intended for 14,389 feet), but this elevation

was determined more than twenty years ago by combining the results obtained by vertical angles and mercurial barometers. In a letter dated August 24, 1905, the acting Director of the Survey states that "doubt is thrown on the value from the fact that an exact elevation of the base station was not known and the methods used would now be considered only approximate." It may be noted, therefore, that the height of 4402 meters, 14,444 feet, which is so generally given in atlases, school geographies, railroad folders, etc., is not accurate.

Shasta is one of three great peaks on the Pacific slope, standing like sentinels in a stretch of seven hundred miles, including the Sierra and the Cascades. These peaks are at such distances from one another and so situated relative to the general motion of the atmosphere in these latitudes as to offer an almost unparalleled opportunity to obtain cross-section data of storm movements, and the temperature and vapor distribution practically from sea-level to elevations exceeding 4267 meters, 14,000 feet. The co-ordinates of these three great peaks are:

Whitney—36° 34′ 33″ N, 118° 17′ 32″ W.

Rainier—46° 51′ 5″ N, 121° 45′ 28″ W.

Shasta—41° 24′ 28″ N, 122° 11′ 49″ W.

The elevations are: Whitney, 4420 meters, 14,502 feet; Rainier, 4387 meters, 14,394 feet;[5] Shasta, 4349 meters, 14,380 feet.

The elevation of Mount Whitney is the true height determined by precise levels; the elevations of Rainier and Shasta as given above are approximate only and were made by McAdie and LeConte in 1905, as stated above, and described in detail in publications of the Sierra Club and in the *Monthly Weather Review*.

About two miles west of Shasta is Shastina, elevation 3790 meters, 12,433 feet. There are six small glaciers surrounding the peak, known as Whitney, Bolam, Hotlum (double), Wintun, and Konwakiton. The mountain is snow-covered throughout the year.

[5] Determination made by the writer in July, 1905, with the help of members of the Sierra Club, using the same instruments, the same methods, and the same men used in measuring Mount Whitney and Mount Shasta. A redetermination of the height by the U. S. Geological Survey in 1912 is 14,368. The true height probably lies between the two values.

the snow cover extending down in an ordinary season to the 2500-meter, 8000-foot, level during midsummer. There are numerous cinder cones and lava flows, showing the volcanic character of the region.

South of Shasta lies Lassen Peak, elevation 3184 meters, 10,437 feet. To the east and north is a large area extending to the Warner Mountains with an average elevation of from 1000 to 1500 meters. The most prominent peaks in this range are: Bidwell, 2606 meters, 8551 feet; Fandango, 2392 meters. 7848 feet; Cedar, 2532 meters, 8308 feet; Warren, 2846 meters, 9668 feet; and Eagle, 3025 meters, 9934 feet.

In the area between the Cascade Range and Warner Range are numerous lakes, of which the best known are Lower Klamath, Tule, Clear, and Goose lakes.

It is of some importance to understand clearly the orography of the district in order to obtain a better comprehension of certain well-marked climatic features. It is essentially a district of local climates, one in which marked differences are found in short distances and where the general air drainage system is modified by surface conditions. The terms northern and southern do not apply in describing the climate of this section, because the isotherms run north and south.

In the summer months the general movement of the air is from the south. This is due to the prevailing westerly winds of these latitudes, so noticeable along the coast. The Coast Range acts as a barrier to the eastward flow of the air, and from observations made with kites and the study of the motion of the lower clouds it would appear that the surface current from the west during summer months is comparatively shallow and indeed is hardly noticeable above the 1000-meter, 3280-foot, level. But a portion of this surface wind passes freely through the gap in the mountains, i.e., through the Golden Gate, and is deflected north in the Sacramento Valley. This constitutes the well-known south wind felt nearly every summer night and materially moderates the heat of the valley. During the long summer, midday and afternoon temperatures are high. There is, for example, during the month of July a difference of 8° C, 15° F, or more in the mean temperatures of Sacramento and San Francisco; and

a difference of 13° C, 25° F, between the mean temperatures of San Francisco and Red Bluff. The temperatures are: San Francisco, 14.6° C, 57.3° F; Sacramento, 22.5° C, 72.5° F; Red Bluff, 27.8° C, 82.1° F. There are probably few localities in the world where there exists so marked a gradient in surface temperature. During the winter months the differences are less marked and there is practically the same temperature at the northern and the southern ends of the valley. The following figures give the mean temperature for January: San Francisco, 9.7° C, 49.5° F; Sacramento, 7.6° C, 45.6° F; Red Bluff, 7.4° C, 45.4° F. The higher temperature at San Francisco is to be explained as due chiefly to its proximity to the ocean, the same cause operating also to give the lower temperature in midsummer.

The rainfall is rather evenly distributed, and on the same level the distribution both as to intensity and frequency is comparatively uniform. There is, however, a marked difference in the amount of rainfall at stations close together but differing in elevation. The amount of rain increases as one goes from the floor of the valley through the foothill section and up the mountain side, reaching a maximum at a height of about 2000 meters, 6560 feet. The records of the stations along the line of the railroad from Sacramento to Summit, covering a period of thirty-six years, show a steady increase in the quantity of rain caught by the gauges of about 1 centimeter, 0.4 inch, for every 11 meters, 36 feet, rise in elevation. The rate of increase is greatest about the 1000-meter, 3280-foot, level and becomes negative above the 2000-meter, 6562-foot, level. At these high levels, however, much of the precipitation falls in the form of snow, and it is possible that with our present methods of reduction true values have not been obtained.

Variation of Rainfall With Altitude

In the *Monthly Weather Review*, July, 1911, Mr. Charles H. Lee gives numerous diagrams showing the rate of increase of precipitation with elevation in various parts of California. Three sections of the Sierra are charted, the first known as the Central Pacific section, extending from Sacramento to Truckee; second, the Mokelumne section, extending from Stockton to Carson Lake,

about fifty miles south of the first group; and third, the Tuolumne section, extending from Merced to the southern end of Walker Lake. The Fresno section then would constitute a fourth, still farther south. From the data it appears that there is a definite increase in precipitation with elevation up to 1500 meters, 5000 feet, decreasing steadily above this. The average rate of increase is 8.5 inches, 215 millimeters, per 1000 feet, 300 meters, up to 1500 meters, 5000 feet.

East of the Sierra crest precipitation decreases rapidly with decrease in altitude, maintaining a constant rate to the 1500-meter, 5000-foot, level and a decreasing rate below this elevation. The distance and precipitation curves conform to the profile in general shape, except that their maxima are west of the topographic crest, occupying the same relative position with respect to the Great Valley as the 1500-meter, 5000-foot, level. They have a tendency to become horizontal over the level portion of the profile, to rise over western slopes below the 1500-meter, 5000-foot, contour, to fall over western slopes above this, and to fall over eastern slopes. In other words, the general slope of the country seems to have more to do with the amount of precipitation than does altitude.

Precipitation upon the plains of northern India and the southern slope of the Himalayas exhibits a similar variation. An empirical equation giving the relation of precipitation and elevation has been developed from observations in that region, as follows: $R = 1 + 1.92\, h - 0.40\, h^2 + 0.02\, h^3$, in which R represents the amount of rain and h the relative height in units of a thousand feet above an assumed plane, which was itself 300 meters, 1000 feet, above sea-level. The critical elevation was 1270 meters, 4160 feet, above sea-level and observations were sufficient to determine that the form of the curve above this elevation was similar to that below, the complete curve approximating a cubic parabola whose axis is the line represented by the critical elevation.

The curves in figures 5 and 6 suggest a similar relation for the west slope of the Sierra, with a critical elevation of about 1500 meters, 5000 feet. The relatively low crest of the latter range, however, breaks the relation just above the critical eleva-

tion, so that the upper arm of the curve is incomplete and a discontinuity is introduced. The relation of precipitation to elevation upon the Sierra is therefore not unique, but conforms to some general law.

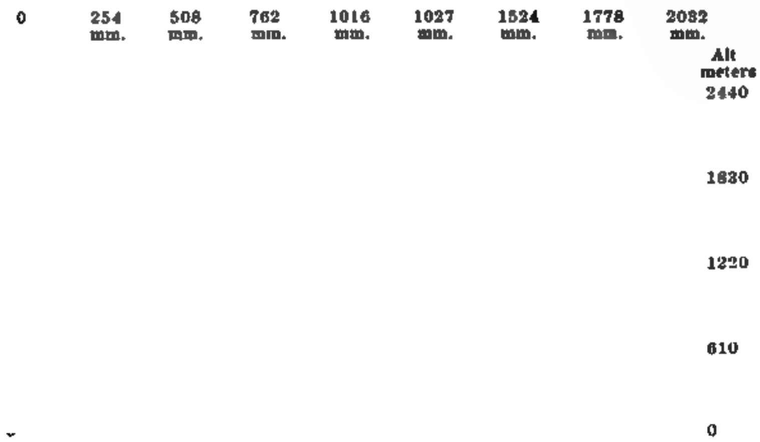

Fig. 5

Relation of altitude and precipitation (Central Pacific Group)
(After C. H. Lee)

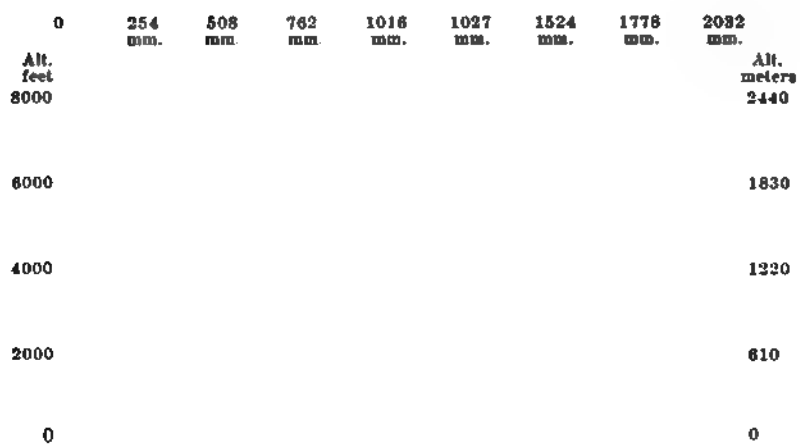

Fig. 6

Relation of altitude and precipitation (Mokelumne Group)
(After C. H. Lee)

The condition met with is the broad slope of a long mountain range presented to a prevailing moisture-laden wind. The movement of a body of moist air up such a slope results in expansion and cooling of the air. When the temperature reaches the dew point, condensation of the aqueous vapor occurs. The latent heat thus liberated tends to warm the air and raises its temperature above the dew point. The descent on the leeward slope of the range is accompanied by a rapid compression and rising temperature of a body of air. Hence, precipitation is greatest along the lower windward slopes of the Sierra and reaches its maxima at the lower cloud limit, the 1500-meter, 5000-foot, contour, decreasing slowly from here to the crest of the range and decreasing rapidly down the leeward slope to the desert. It is, therefore, not increasing elevation alone which causes increase in precipitation, but broad, rising slopes which give an upward movement to bodies of moist air driven by prevailing winds.

The conclusions from this study which can be applied in practical computations are as follows:

1. The precipitation upon the west slope of the Sierra between the Yuba and Tuolumne rivers increases at a variable rate, which, expressed as an average, is 21.5 millimeters per thirty-meter rise, 0.85 inch per hundred-foot rise, from the floor of the Great Valley to the 1500-meter, 5000-foot, contour.

2. Above the 1500-meter, 5000-foot, contour it decreases approximately at the rate of 10 millimeters per thirty-meter rise, 0.40 inch per hundred-foot rise, to the crest of the Sierra.

3. Precipitation upon the east slope of the Sierra decreases at differing rates, depending upon the elevation of the crest and depth of precipitation at the summit. The rate is constant above the 1500-meter, 5000-foot, contour, and for the sections studied is as follows:

Central Pacific, 44 millimeters in 30 meters, 1.74 inches per hundred-foot fall.

Mokelumne, 36 millimeters in 30 meters, 1.43 inches per hundred-foot fall.

Taboose and Oak, 12 millimeters in 30 meters, 0.46 inch per hundred-foot fall.

Bairs, 9 millimeters in 30 meters, 0.34 inch per hundred-foot fall.[6]

For data relating to increase of rainfall with elevation in the San Joaquin Valley see page 158, and for similar data regarding southern California see page 164.

CENTRAL CALIFORNIA

The portion of California included under this head is bounded on the north by a line drawn from San Francisco to Lake Tahoe; on the east by the Sierra Nevada; on the south by a line drawn from Point Conception south of Bakersfield and including the Kern watershed; and on the west by the Pacific.

The most prominent features are the bay of San Francisco, that portion of the great valley known as the San Joaquin, and the coast valleys, embracing the Santa Clara, the Salinas, and other smaller valleys.

The bay of San Francisco is one of the great harbors of the world. While there is a continuous water passage from the Pacific Ocean to the delta formed by the Sacramento and the San Joaquin rivers, the bay is locally considered as embracing only the central and southern portions of the water surface; the northern portion being known as San Pablo Bay, which in turn is distinguished from Suisun Bay lying to the east and connected with the former by the Straits of Carquinez. The length of the bay proper, in a northwest and southeast line, is about sixty-six kilometers, or forty-two miles, and the width varies from eight to twenty-one kilometers, five to thirteen miles. At mean tide the area of the bay, exclusive of San Pablo and Suisun bays, is about four hundred and fifty square miles. The combined areas

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6 Mr. Wilhelm Krebs has called my attention to the results of measurements made by him on the Storm and Draken mountains in South Africa, published in the *Deutsche Rundschau fur Geographie und Statistik*, August, 1890, and September, 1908. He applies the same process to the Sacramento and San Joaquin records, using as the base line of the gradient Sacramento and Stockton. He finds that the ratio of Auburn elevation to Gold Run elevation is as 1 to 2.4; the precipitations, 1 to 1.6, and the gradients of the slope, 1 to 1.5. The ratio of Auburn and Blue Cañon is as 1 to 3.6, the precipitations as 1 to 2.1, and the gradients of the slope as 1 to 1.9. He also compares Mokelumne Hill, West Point, and Bear Valley. The ratio of precipitation agrees with the gradients of slope and differs from the ratio of elevations.

amount to about nine hundred square miles. The bay is connected with the Pacific Ocean by a narrow water passage varying in width from two to five kilometers, one to three miles, and about ten kilometers, six miles, long. This is known as the Golden Gate. The city of San Francisco lies on the southern side of the Golden Gate, occupying the end of the peninsula, which is here about eleven kilometers, seven miles, wide. The area occupied by the city amounts to about fifty square miles.

The climate of San Francisco is so out of the usual that it has attracted general attention. There are noticeable features, such as the fogs and the low temperatures in midsummer, which are not found in such marked degree elsewhere. The climatic features of this district are discussed in detail elsewhere.[7]

San Joaquin Valley

From the city of Stockton to Bakersfield the floor of the valley is approximately three hundred and fifty kilometers, two hundred miles, long, with an average width of eighty kilometers, fifty miles. There are comparatively few lakes, the largest being Tulare, with an area of less than four hundred square miles, the water line varying in different seasons. Buena Vista Lake and Kern Lake lie in the extreme southern end of the valley. The foothills of the Coast Range bound the western side of the valley. There are several mountain ranges in the main range, running nearly parallel to the coast. The more prominent are Hamilton, Temblor, and San Emigdio.

The Sierra Nevada bounds the valley on the east, the foothills sloping gradually. The range culminates in the so-called "High Sierra" in the eastern portions of Fresno and Tulare counties. Mount Whitney, the highest point in the United States proper, has an elevation of 4420 meters, 14,502 feet. In Bulletin L, "Climatology of California," there is given a list of seventy-two peaks, the heights of which were determined by Professor J. N. LeConte in 1903. Of these, sixty-six exceed 3048 meters, 10,000 feet, and forty exceed 3963 meters, 13,000 feet. The summits of many peaks are snow-clad throughout the year. At elevations of

[7] See McAdie, A. G., "Climate of San Francisco," U. S. Weather Bureau Bulletin 44, 1913; Reed, W. G., "The Rainfall of Berkeley, California," Univ. Calif. Publ. Geog., vol. 1, no. 2, pp. 63–79, 1913.

about 2000 meters, 7000 feet, snow disappears and the ground is bare during July, August, and September. Reliable records in the high levels are scanty. Temperatures as low as —34° C, —30° F, have been reported, and in all probability even lower temperatures have occurred. On the other hand, midsummer afternoon temperatures have been as high as 32° C, 90° F. During the winter of 1898 a minimum thermometer was exposed near the summit of Mount Lyell, 4028 meters, 13,217 feet; the lowest temperature recorded was —27° C, —17° F. During the same period temperatures seven degrees centigrade lower were reported from stations having an elevation of but 2438 meters, 8000 feet.

Maximum and minimum thermometers were placed in a small shelter on the north wall of the observatory on Mount Whitney, elevation 4420 meters, 14,502 feet, in September, 1909. On May 24, 1910, Mr. G. F. Marsh, co-operative observer, succeeded in reaching the summit and found the instruments in the condition in which they were left. The minimum temperature was —31° C, —23° F, and the maximum temperature 13° C, 55° F.

In the *Monthly Weather Review* for May, 1910, the writer called attention to this reading as fairly representing the lowest temperature of that winter at the highest point in the United States proper. Lower temperatures were recorded in California during this same period, for example, —34° C, —29° F, at Alturas on January 3, 1909, elevation 1360 meters, 4460 feet, and —34° C, —29° F, at Tamarack, elevation 2440 meters, 8000 feet, January 5, 1909.

On September 26, 1912, the instruments were reset. Mr. F. H. Criss, who read the instruments, states that minimum thermometer No. 1270 indicated a temperature of —37° C, —35° F. The maximum temperature was 18° C, 65° F.

The following low temperatures were reported during 1911:

	Elevation		Temperature		
	Meters	Feet	° C	° F	Date
Sierraville	1,524	5,000	—34	—30	Feb. 16
Tamarack	2,438	8,000	—32	—26	Dec. 30
Madeline	1,606	5,270	—31	—24	Jan. 22
Truckee	1,773	5,819	—30	—22	Feb. 26
Alturas	1,359	4,460	—29	—21	Dec. 23

During 1912, Alturas, —32° C, —26° F, January 3; Sierraville, —31° C, —24° F, January 3.

Regarding the general climatic features of the San Joaquin Valley, it may be said that the precipitation is less than might be expected. There is a practically rainless period from May to September. In some seasons there are afternoon thunderstorms in the foothills and occasional light rains. Of a seasonal rainfall amounting to about ten inches in the central portion of the valley, less than half an inch falls during the months of June, July, August, and September. The month of greatest rainfall is December, with an average of less than two inches. Notwithstanding the somewhat limited rainfall, the valley and foothill regions constitute the chief agricultural sections of the state. Apricots, cherries, almonds, walnuts, peaches, pears, plums, grapes, figs, and olives are grown most successfully. Citrus fruits of all kinds flourish in the foothill section. It may also be pointed out that this is the only section of the United States in which raisin-making is carried on.

The summer afternoon temperatures are exceedingly high. At Fresno a maximum temperature of 46° C, 115° F, has been recorded, and temperatures of from 38° to 43° C, 100° to 110° F, are not unusual in the midsummer months. Owing to intense radiation the diurnal range of temperature is large, the difference between the extremes frequently amounting to 20° C, 40° F, or more. During the winter months the temperature falls to the freezing point or below. The lowest temperature recorded at Fresno was —8° C, 17° F, on January 16, 1913. This was the coldest weather ever experienced in this section. Frosts occur frequently during the winter months, the first killing frosts occurring about the beginning of December and the last about the end of March.

The prevailing winds are from the north and occasionally they are strong and do damage, especially during the first part of June when the wheat is about ready for harvest. The summer days are as a rule cloudless. During the winter months, under certain pressure distribution, a low-lying land fog forms during the night and morning hours. This stratum of ground fog is not very deep, often not exceeding 30 meters, 100 feet, and is

confined chiefly to the river courses and bottom lands. The foothill sections are for the most part above these winter fog belts.

VARIATION OF RAINFALL WITH ALTITUDE

In the *Monthly Weather Review* for September, 1911, page 1422, there was published a discussion of the rainfall records of four stations near Fresno for the seasons 1909–10 and 1910–11. The data was supplied through the courtesy of Mr. E. J. Crawford, assistant general superintendent of the San Joaquin Light and Power Corporation. The stations are:

	Elevation	
	Meters	Feet
Fresno	70	230
San Joaquin power house	309	1,013
Reservoir No. 1	744	2,441
Colorado Valley Dam	1,067	3,500

By combining the records the following annual amounts were determined for the various elevations:

	Rainfall	
	Mm.	Inches
70 meters, 230 feet	289.6	11.40
309 meters, 1,013 feet	800.9	31.53
744 meters, 2,441 feet	803.4	31.63
1,067 meters, 3,500 feet	1274.1	50.16

Or a gradient of 96.9 millimeters per 100 meters, 1.18 inches per 100 feet.

Attention was called to an apparent irregularity in the rate of increase between the second and third stations. Mr. Crawford has offered the following reasonable explanation: The 300-meter, 1000-foot, elevation represents a locality on the main San Joaquin River so situated that the 600-meter, 2000-foot, level has to be passed over before the 300-meter, 1000-foot, level is reached. In other words, the power house, itself at an elevation of a little over 300 meters, 1000 feet, is surrounded by hills exceeding 600 meters, 2000 feet. The amount caught at the lower level is practically the same as that of the higher elevation.

Mr. Crawford furnishes the following additional data for the season of 1911–12:

Months	Fresno	San Joaquin power house	Reservoir No. 1	Colorado Valley Dam
September	0.01	0.06	0.08	0.30
October	.09	.07	.08	.25
November	.17	1.45	1.27	2.62
December	1.06	1.18	1.78	3.49
January	.72	.64	2.18	2.90
February	.00	.08	.09	.34
March	3.02	6.02	5.66	9.61
April	1.86	3.55	3.67	7.00
May	.41	.77	.75	1.58
June	.00	.00	.00	.11
July	....	....	....	....
August	....	....	....	....
Total	7.34	13.82	15.56	28.20

For the three seasons 1909–10, 1910–11, and 1911–12 we find that the seasonal rainfalls average:

	Rainfall	
	Mm.	Inches
70 meters, 230 feet	255.3	10.05
309 meters, 1,013 feet	651.0	25.63
744 meters, 2,441 feet	667.3	26.27
1,067 meters, 3,500 feet	1088.1	42.84

Neglecting the second station, for the reason above stated, we find that the average increase up to 1070 meters, 3500 feet, is at the rate of 820 millimeters per 100 meters, 1 inch per 100 feet; the average increase up to 744 meters, 2441 feet, is at the rate of 58.1 millimeters per 100 meters, 0.73 inch per 100 feet; while the average rate of increase in the level between 744 meters, 2441 feet, and 1067 meters, 3500 feet, is at the rate of 119 millimeters per 100 meters, 1.45 inches per 100 feet.

Salinas Valley

The next largest valley in central California is the Salinas Valley, which lies west and southwest of the San Joaquin. Beginning at the mouth of the Salinas River, on the southern side of Monterey Bay, the valley extends southeastward through Monterey and San Luis Obispo counties, nearly 160 kilometers, 100 miles, with an average width of 16 kilometers, 10 miles.

On the west side of the valley the Santa Lucia range rises with an average altitude of 1200 meters, 4000 feet. On the east side the valley is bounded by the various minor ranges forming the western boundary of the San Joaquin.

The coldest month is January and the warmest July. In the central part of the valley the mean annual rainfall is less than 400 millimeters, 15 inches. There are years, however, when the amount exceeds 500 millimeters, 20 inches, and, on the other hand, there have been two years in a period of thirty-seven when the annual rainfall did not exceed 175 millimeters, 7 inches. Both of these were unusually dry years in California. The rainfall is fairly well distributed for agricultural purposes. In the summer months strong winds prevail, but from November to March the prevailing wind is south.

The city of Salinas has a mean annual temperature of 13° C, 56° F. The highest temperature recorded was 36° C, 96° F, and the lowest —7° C, 20° F.

Santa Clara Valley

The Santa Clara Valley lies between the Santa Cruz Mountains on the west and the Mount Hamilton range on the east. The prevailing westerly winds, intensified by the formation of the Golden Gate, are deflected up the Santa Clara Valley as strong north winds. There are well-marked differences in temperature and rainfall between the valley and the coast. The mean annual rainfall at San Francisco is about 600 millimeters, 23 inches, and at San José about 400 millimeters, 15 inches. In other words, in going south a distance of eighty kilometers, fifty miles, there is a steadily decreasing rainfall, amounting to about 203 millimeters, eight inches, in the distance named. The Lick Observatory is situated on Mount Hamilton at an elevation of 1283 meters, 4209 feet, above sea-level. The station is about twenty-three kilometers, fourteen miles, east of the city of San José. The mean annual precipitation is about 800 millimeters, 32 inches, or nearly double that of the floor of the valley. Rain falls in every month of the year on Mount Hamilton, but the summer rains are limited to light showers. More than half the annual rainfall occurs between December and March.

San José, the county seat of Santa Clara County, and most prominent city in the valley, lies eighty kilometers, fifty miles, south of San Francisco and about thirteen kilometers, eight miles, south of the lower end of San Francisco Bay. The elevation varies from twenty-four to thirty meters, eighty to one hundred feet, above sea-level, but within a few miles from the center of the city the foothills rise to heights exceeding 300 meters, 1000 feet. The general movement of the air is from the north, and the valley is somewhat sheltered from the strong westerly winds prevalent on the coast. Summer fogs are not carried over the western hills, but hang in beautiful cascades along the ridge. There is a marked difference in the amount of bright sunshine during summer afternoons between the valley, especially that portion near San José, and San Francisco. Low winter fogs sometimes occur, but as a rule do not last long.

The mean annual temperature of the lower end of the valley is 14° C, 58° F. The coldest month is January, with a mean temperature of 9° C, 48° F, and the warmest month, July, mean temperature 19° C, 67° F. The highest temperature recorded is 40° C, 104° F, and the lowest temperature —8° C, 18° F.

California South of the Tehachapi

This division embraces Santa Barbara, Ventura, Los Angeles, Orange, Riverside, San Diego, Imperial, and San Bernardino counties. It is bounded on the north by the Sierra Madre, on the east by the Colorado River, on the south by Mexico and the Pacific, and on the west by the Pacific. The most important section is the San Gabriel Valley. The most important city is Los Angeles, situated in a valley of the same name. The center of the city was originally twenty-nine kilometers, eighteen miles, from the ocean, but recent extension of the city's boundaries to include San Pedro makes the city a seaport. Within a distance of ninety-seven kilometers, sixty miles, there are many smaller cities and towns, of which may be mentioned Pasadena, Riverside, Redlands, and San Bernardino. The mountains to the north rise abruptly and form a wall varying from 1500 to 3000 meters, 5000 to 10,000 feet, in elevation. Some of the best known peaks are

Mount Lowe, elevation 1042 meters, 3420 feet; Mount Wilson, 1770 meters, 5800 feet; and San Antonio, commonly known as "Old Baldy," 3070 meters, 10,080 feet. These can be seen from elevated places in the valley. On the eastern side lie the San Bernardino Mountains, with an average elevation exceeding 1800 meters, 6000 feet. Some of the best known peaks in the range are San Bernardino, 3075 meters, 10,630 feet, and San Gorgonio, 3196 meters, 11,485 feet, locally known as "Old Grayback," the highest peak in southern California.

The southwestern half of the district is drained by the Santa Ana River, which has its source in the San Bernardino Mountains, traversing San Bernardino Valley and breaking through the Santa Ana Mountains between Rincon and Yorba, after which it is diverted for irrigation in the comparatively level lowlands around Orange, Santa Ana, Anaheim, and Fullerton. The western portion is drained by the San Gabriel River, which rises near the backbone of the Sierra Madre and flows westerly through various cañons, reaching lower levels near Azusa. It then flows southerly through the San Gabriel Valley and the Los Angeles Valley, emptying into the Pacific Ocean in a delta east of Long Beach. A third stream is the Los Angeles River, formed by a number of small creeks uniting east of Los Angeles and entering the Pacific west of Long Beach.

The topography favors a drainage of the air from the mountains seaward at certain hours and a return flood or movement of the surface air from the sea inland at certain other hours. In other words, the conditions are extremely favorable for the development of air streams which reverse their direction at least twice in each 24-hour period. (See fig. 7.)

In general the lower air flows to the southwest during the night and early morning hours and to the northeast during the afternoon hours. During the winter months when areas of high pressure pass over the Great Basin the surface air apparently moves south, crossing the northern flank of the Sierra Madre and descending with some momentum into the valley. The wind movement is particularly marked in the vicinity of the mountain passes, a good illustration being near Cajon Pass, 1165 meters, 3823 feet. During these so-called "northers," also

of about —3° C, 26° F, in the orange orchards. At many points, especially in the lower lands, care must be taken to protect oranges and lemons from both the fall in temperature and the rather rapid rise which occurs about eight o'clock in the morning. In various papers published by the Weather Bureau the best methods of protecting fruits have been discussed.

Variation of Rainfall With Altitude

Mr. Fred G. Plummer, in a bulletin on chaparral (U. S. Forest Service Bulletin 85), gives the following estimate of the average annual precipitation over the chaparral area in southern California:

	Mm.	Inches
At sea level	330	13
At 600 meters, 1,970 feet—		
West and south slopes, 25; East and north slopes, 9	430	17
At 1,500 meters, 4,920 feet—		
West and south slopes, 43; East and north slopes, 27	880	35
At 2,500 meters, 8,210 feet—		
West and south slopes, 61; East and north slopes, 45	1,350	53

San Diego

In the extreme southwestern portion of the general division lies San Diego, located on the bay of the same name. The city is the oldest one on our Pacific Coast. Weather records have been maintained for a period of sixty-two years. The climate of the city is described in detail elsewhere.[8] In general the rainfall is light, seldom exceeding 250 millimeters, 10 inches, and over 80 per cent of the amount falls between October and March. There is, however, a much heavier rainfall in the mountains to the northeast, and the annual rainfall at an elevation of 1000 meters, 3280 feet, amounts to 1500 millimeters, 60 inches. On the eastern slopes of the mountains the precipitation diminishes rapidly. In the Colorado Desert, particularly that portion known as the Salton Desert, the annual rainfall does not exceed 75

[8] Carpenter, Ford A., "The Climate and Weather of San Diego, California," published by the San Diego Chamber of Commerce, 1913.

millimeters, 3 inches. There is, therefore, a marked variation in rainfall within comparatively short distances. It is worth noting that the heaviest rainfall for a short period in the United States occurred in the form of a cloudburst in this section. On August 12, 1891, according to Mr. Archibald Campbell, co-operative observer, there fell at Campo 409 millimeters, 16.10 inches, during a storm of the "Sonora" type. In the *Monthly Weather Review* for October, 1906, a description of this particular storm and other "Sonoras" is given by Mr. Campbell. The date, however, is incorrectly given as August, 1890, and the rainfall did not all occur within twenty-four hours. The twenty-four hour rainfall was 292 millimeters, 11.50 inches. In a period of about eighty minutes 292 millimeters, 11.50 inches, fell, so far as can be ascertained.

Imperial Valley

The Salton Sink is a portion of an ancient lake, and it has been proposed by William P. Blake, who discovered the Salton Sink, that the original lake be named Cahuilla, as distinguished from the Salton Sea or present body of water, which does not rise to the ancient lake level, just as Salt Lake, for example, is known to be the remnant of the greater lake Bonneville. The area of the Salton Sea during its most recent period of expansion, 1907–08, was about four hundred square miles. The surface is approximately 60 meters, 200 feet, below mean sea-level. Previous to the flooding the lowest point of the sink was 91.4 meters, 273.5 feet, below mean sea-level. The general relations of the region are shown in figure 8.

The valley lies to the south of the sea, extending to the Mexican line, and contains approximately half a million acres of highly fertile land, sloping gently from the south. The Colorado River about ninety-seven kilometers, sixty miles, east is tapped at several points, and a supply of water for irrigation purposes thus provided. The valley has now substantial agricultural interests. Cotton is one of the chief products of this section. Brawley, Imperial, El Centro, Holtville, and Calexico are the chief incorporated towns.

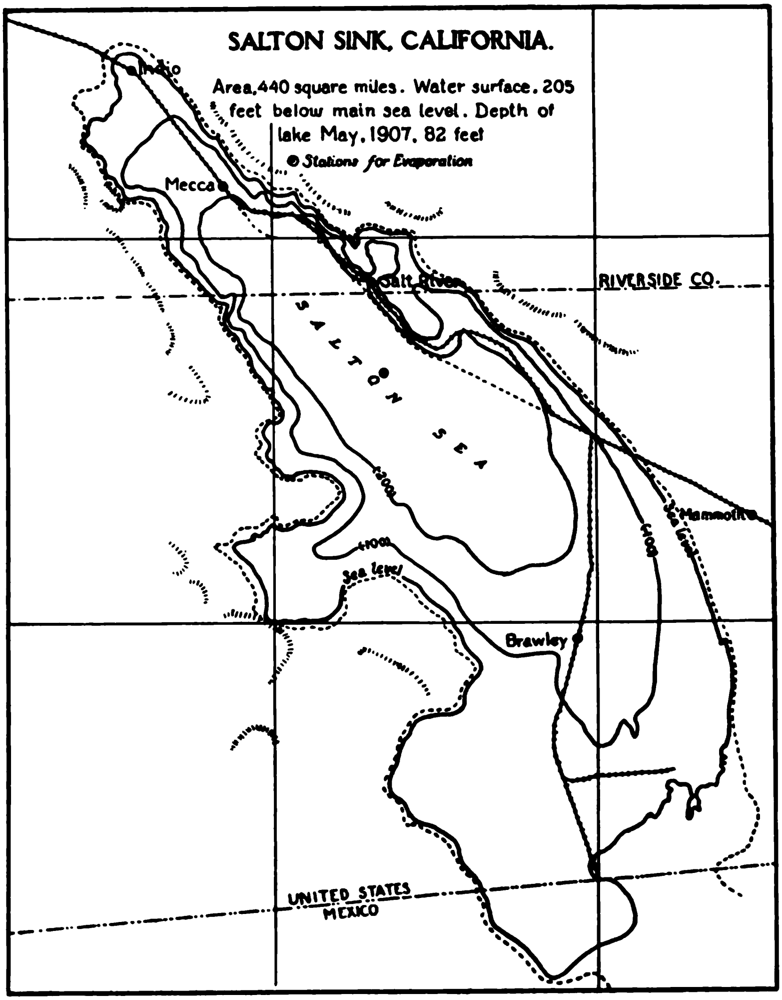

Fig. 8
Sketch map of Imperial Valley region

The climate is one of high afternoon temperature during the summer months and extreme dryness. During 1911 the highest temperature recorded at Brawley was 45.5° C, 114° F, on July 30, and the lowest, —7° C, 20° F, on December 24. The annual mean temperature was 21.2° C, 70.2° F, the monthly mean for January, 12° C, 54° F, and for July 32.2° C, 90° F.

The rainfall at Calexico during 1911 amounted to 34.3 millimeters, 2.35 inches, distributed as follows: January, 11.9 millimeters, 0.47 inches; February, 22.1 millimeters, 0.97 inches; March, 3.3 millimeters, 0.13 inch; July, 8.4 millimeters, 0.33 inch; and October, 11.4 millimeters, 0.45 of an inch. As a rule little rain falls from the storms of the North Pacific. During the period from July to October occasional heavy rains occur in connection with the Sonora type of storm. The winds are mostly northwesterly in winter and easterly in summer.

During the overflow of 1907, when the Colorado River broke through an improperly built headgate and reached the Alamo and New rivers, thence flowing north into the Salton Sea, there was much discussion as to the effect which the newly formed or rather increased area of water would have upon the climate of the section, particularly in the matter of rainfall. Many held that there was an increase in rainfall, cloudiness, and relative humidity. In the *Monthly Weather Review* for December, 1906, Professor A. J. Henry discusses the problem and comes to a decision in the negative.

California East of the Sierra

Owens Valley

There is a section of California lying east of the Sierra Nevada and north of the Sierra Madre to which the general name of Owens Valley has been given, because of the lake and river of the same name. The valley is about 161 kilometers, 100 miles, long, with an average width of forty kilometers, twenty-five miles. The northern end has an elevation exceeding 1200 meters, 4000 feet, and the slope is to the south. The Owens River, from which the city of Los Angeles obtains its supply of water, is fed by a number of mountain streams due to the snows of the high Sierra. While the water of the river is fresh, the water of Owens Lake, into which it empties, is too saline for potable purposes. The river channel lies close to the base of the Inyo Mountains, which bound the valley on the east. Detailed description of the character of the valley floor, the run-off of the various streams and the amount of water in the soil can be found

in various papers published by the engineer corps of the Los Angeles Aqueduct.[9] Reference may also be made to papers in the *Monthly Weather Review* for January, 1910, by Charles H. Lee and A. B. Wollaber.

The best known town in the section is Independence, where weather records have been kept, but not continuously, since 1865. This section of the Great Basin has been known for many years as "the land of little rain." At Independence, elevation 2098 meters, 3907 feet, the mean seasonal rainfall is 88.4 millimeters, 4.48 inches; Bishop, 1361 millimeters, 5.36 inches.

Death Valley

This valley lies partly in California (southeastern portion of Inyo County) and partly Nevada (southern portion of Nye County).

A few years ago this portion of the old "Great American Desert" was accessible only by teams from Goldfield, Nevada. Now, however, the Tonopah and Tidewater Railroad traverses the section formerly dreaded, and within the last year a co-operative station has been established at Greenland Ranch, a few miles southwest of Ryan, which in turn is four miles southwest of Death Valley Junction on the Tonopah and Tidewater Railroad.

The name Death Valley is given to this section because of the loss of a party of emigrants in 1849, and subsequent numerous deaths of prospectors. During the summer months afternoon temperatures frequently reach 49° C, 120° F. As in other portions of the desert, however, the nights are generally cool. The valley is below sea-level, the lowest point thus far determined being 177 meters, 280 feet, below.

Hygrographic records at Greenland Ranch for the year 1912–13 show that while humidities are generally low there are periods when a high degree of saturation prevails. The humidity is not so low as might be anticipated; and the records uphold

[9] See annual reports of the Bureau of the Aqueduct, Los Angeles Board of Public Works; Lee, C. H., Water Resources of Part of Owens Valley, California, U. S. Geol. Survey Water Supply paper 294, 1912.

the belief that it is quite possible, if proper care be taken in the matter of supplies and provisions for physical comfort, to live and work in this section.

The highest temperatures recorded during 1913 were June 22, 48° C, 119° F; July 4, 52° C, 125° F; August 24, 51° C, 124° F.

EXCESSIVE RAINS IN CALIFORNIA

In an article in the *Monthly Weather Review*, July, 1912, page 1062, Mr. Edward D. Coberly gives an extensive tabulation of all monthly rainfalls of 250 millimeters, 10 inches, or more and of all amounts of 100 millimeters, 4 inches, or more in twenty-four hours that have occurred in the state of Louisiana. It has occurred to the writer that a somewhat similar table for California would be of value, not only for engineers and others interested in power questions, but also for students of climatology who may be interested in studies of heavy rainfall in various parts of the United States.

It is evident from the figures that follow that certain portions of California may well be considered as lying within the zone of maximum intensity of rainfall in the United States. It may also be noted that the records are of comparatively recent date and have been made with standard eight-inch gages properly exposed.

The table on page 170 shows the heaviest recorded rainfall in California during the past ten years: The greatest annual amount is 3900 millimeters, 153.54 inches, at Monumental, Del Norte County, exact elevation not determined. This occurred in 1909. This is not given in the list compiled by Mr. Coberly, although in excess of any of the rainfalls quoted for places in the United States, except Glenora, Oregon, record of 1896, when 4250 millimeters, 167.29 inches, fell, and the same place in 1897, when 3969 millimeters, 156.50 inches, fell.

Rainfalls exceeding 2540 millimeters, 100 inches, have occurred at many points in California. From an inspection of long-period records made at several stations in California, we are justified in concluding that the year 1909 in California was the

EXCESSIVE ANNUAL RAINFALL IN CALIFORNIA

Stations	Elevation Meters	Elevation Feet	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902
Monumental	....	....	....	....	153.54	88.59	139.20	116.13	69.30	....	....	....
Magalia	708	2,321	77.62	49.32	150.62	44.96	96.32	125.01	48.16	94.40	....	....
La Porte	1,524	5,000	....	60.22	141.40	58.08	113.94	124.46	....	....	77.04	89.09
Helen Mine	838	2,750	73.81	50.76	136.86	53.90	103.13	129.69	68.03	114.72	67.37	137.58
Inskip	1,516	4,975	78.49	58.08	134.18	56.42	....	....	....	....	....	....
Branscomb	610	2,000	65.17	56.49	130.14	59.06	108.42	99.08	55.03	115.07	91.06	120.35
Woodleaf	991	3,250	....	....	125.28	....	103.18	125.41	....	....	....	....
Fordyce Dam	1,981	6,500	71.03	47.41	125.28	41.88	86.14	120.64	43.16	75.69	63.31	65.59
Bear Valley (Nevada Co.)	1,402	4,600	72.75	49.44	119.39	45.47	94.47	110.85	46.93	103.59	67.44	....
Pilot Creek	1,219	4,000	79.94	44.01	113.98	41.96	87.15	110.61	42.56	93.99	68.66	60.70
Blue Cañon	1,431	4,695	67.27	42.13	110.72	40.97	100.17	104.21	46.65	93.48	64.18	64.99
Stirling City	1,073	3,525	66.20	35.75	108.63	33.56	111.20	125.08	44.02	....	....	....
Brush Creek	652	2,140	66.53	37.62	104.65	48.57	86.64	106.25	50.63	91.98	....	....
Nimshew	762	2,500	65.70	40.36	103.26	44.82	82.21	104.00	43.11	....	....	....
Crescent City	15	50	....	....	....	53.35	91.46	70.27	50.91	107.61	80.76	103.12
Upper Mattole	75	244	64.13	62.81	121.79	61.93	99.84	85.70	70.04	126.53	94.88	123.26
Bowmans Dam	1,672	5,500	....	....	113.85	47.27	86.55	97.45	64.49	135.70	88.70	70.92

year of heaviest rainfall. The years 1871, 1879, 1880, 1882, 1884, 1893, 1896, 1899, 1904, 1907, and 1911 were all years of heavy rainfall; but it is doubtful if the total amount at any one station was in excess of that which fell during 1909.

Other heavy annual rainfalls were:

	Mm.	Inches
During 1909—		
Camptonville	3464.0	136.38
Deer Creek	3137.0	123.31
Delta	2916.2	114.85
Downieville	2581.6	101.64
Head Dam	2543.6	100.14
Kennett	2944.4	115.92
West Branch	3034.1	119.45
During 1884—Bowmans Dam	3038.8	119.64
During 1889—		
Delta	2820.7	111.05
Upper Mattole	2543.8	101.25
During 1890—Bowmans Dam	2610.6	102.88
During 1896—		
Bowmans Dam	2792.5	109.94
Bear Valley	2599.4	102.34
Delta	2546.9	100.27
La Porte	3053.1	120.20
Upper Mattole	2604.0	102.52
During 1889—La Porte	2566.4	101.04

Heaviest Monthly Rainfalls in California

Apparently the heaviest monthly rainfall in the United States occurred in California, at Helen Mine, January, 1909, when 1817 millimeters, 71.54 inches, fell. The following table shows excessive monthly amounts at a number of stations in California during January, 1909:

	Mm.	Inches
Bear Valley (Nevada Co.)	1,245	49.02
Ben Lomond	1,081	42.57
Blue Cañon	1,228	48.35
Boulder Creek	1,001	39.42
Bowmans Dam	1,207	47.53
Branscomb	1,417	55.79
Brush Creek	1,178	46.39
Camptonville	1,408	55.43
Deer Creek	1,430	56.32
Delta	1,353	53.28

	Mm.	Inches
Downieville	1,087	42.81
Fordyce Dam	1,410	55.53
Head Dam	1,042	41.03
Helen Mine	1,817	71.54
Kennett	1,374	54.08
La Porte	1,613	63.52
Laytonville	1,176	46.50
Magalia	1,645	64.77
Monumental	1,114	43.84
Mount St. Helena	1,024	40.33
Pilot Creek	1,276	50.25
Stirling City	1,311	51.63
Upper Mattole	1,215	47.84
Woodleaf	1,602	63.08
West Branch	1,618	63.71

The heaviest monthly rainfalls at regular Weather Bureau stations during entire period of record are:

	Mm.	Inches
San Francisco, January, 1862	618.8	24.36
Sacramento, January, 1862	382.0	15.04
Eureka, February, 1902	495.0	19.49
Red Bluff, November, 1885	433.1	17.05
Los Angeles, December, 1889	401.3	15.80
San Diego, February, 1884	230.0	9.05
Independence, December, 1867	309.6	12.19
San Luis Obispo, January, 1909	431.8	17.00
Mount Tamalpais, January, 1909	397.0	15.63
Point Reyes, January, 1909	248.4	9.78
San José, December, 1890	268.0	10.55
Fresno, December, 1909	114.3	4.50
Southeast Farallon, January, 1909	207.8	8.18

HEAVIEST 24-HOUR RAINFALLS

While the record for maximum monthly rainfalls apparently lies with California, the record for the greatest 24-hour rainfall in the United States is probably that mentioned by Mr. Coberly, 544 millimeters, 21.4 inches, at Alexandria, Louisiana, June

15–16, 1886. At Montell, Texas, June 28–29, 1913, 523 millimeters, 20.6 inches, fell in 18 hours and 30 minutes. In this connection, it is interesting to refer to the rainfall record made at Baguio, Philippine Islands, July 14 to 15, 1911, published as plate 5 of the Manila *Weather Bureau Bulletin* for July, 1911. The record made on a Friez quadruple register shows that the total rainfall from noon July 14 to noon of the next day was 1168 millimeters, 45.99 inches. The greatest hourly amounts were 91 millimeters, 3.60 inches, and 90 millimeters, 3.54 inches; the greatest rainfall in ten minutes was 18 millimeters, 0.72 of an inch, and for five minutes, 10 millimeters, 0.40 of an inch. The total precipitation at Baguio for the four days, July 14 to 17, inclusive, was 2239 millimeters, 88.85 inches. This is probably the finest and most reliable rainfall record that has yet been made during periods of excessive rain. In passing it is interesting to note that the rainfall continued to be excessive for several days.

In California, the heaviest rainfall for a short period occurred at Campo, August 12, 1891. The 24-hour rainfall was 292 millimeters, 11.50 inches, so far as can be ascertained, and this fell practically within eighty minutes. The total amount for the storm, or cloudburst as it was known, was 409 millimeters, 16.10 inches. On March 12, 1906, at Mono Ranch, Ventura County, during a period of heavy rain, it was reported that 292 millimeters, 11.50 inches, fell in twenty-four hours. At Monumental 243.8 millimeters, 9.60 inches, fell in twenty-four hours November 22, 1909; on the previous day 153.7 millimeters, 6.05 inches, fell, and on the day following 71.1 millimeters, 2.80 inches.[10]

[10] Mr. C. F. Brooks has furnished for comparison the following records of excessive precipitation:

Period	Amount	Date	Place
24 hours	1168 mm.	July 14–15, 1911	Baguio, P. I.
24 hours	544	June 15–16, 1886	Alexandria, La.
18½ hours	523	June 28–29, 1913	Montell, Tex.
3 hours	406	August 5, 1843	Concord, Pa.
80 minutes	292	August 12, 1891	Campo, Cal.
30 minutes	235	August 24, 1906	Guinea, Va.
20 minutes	205	July 7, 1889	Curtea de Argres, Roumania
14 minutes	100	June 4, 1871	Galveston, Tex.
5 minutes	38	May 27, 1868	Fort McPherson, Neb.
30 seconds	4	June 11, 1912	Valdivia, Chile

24-HOUR RAINFALLS, 127 MILLIMETERS, 5 INCHES, OR MORE

	Mm.	Inches
February, 1902—		
Ben Lomond	104.7	5.54
Branscomb	167.6	6.60
Calistoga	166.9	6.57
Delta	139.7	5.50
Healdsburg	143.5	5.65
Laurel	128.3	5.05
Mount St. Helena	177.8	7.00
Zenia	142.2	5.60
N ,		
Branscomb	172.7	6.80
Mercury	128.5	5.06
January, 1903—		
Bowmans Dam	238.5	8.39
Crescent City	180.1	7.09
Shasta	128.0	5.04
Summerdale	163.6	6.44
Upper Mattole	134.6	5.30
March, 1903—		
Laurel	148.8	5.86
November, 1903—		
Branscomb	147.3	5.80
Colfax	127.5	5.02
Shasta	164.1	6.46
Upper Mattole	147.8	5.82
	170.2	6.70
	131.6	5.18
Brush Creek	145.3	5.72
Felton	142.0	5.59
Kentfield	159.3	6.27
Laurel	128.3	5.05
Nimshew	154.1	6.08
Pilot Creek	158.8	6.25
Pino Grande	228.6	8.00
Stirling City	152.4	6.00
February, 1904—		
Branscomb	199.4	7.85
La Porte	143.0	5.63
Mercury	174.8	6.88
Nevada City	141.2	5.56
Quincy	135.1	5.32
San Rafael	160.5	6.32
Shasta	167.1	6.58
Willits	144.0	5.77
Zenia	127.5	5.02
Bear Valley, Nevada Co.	152.4	6.00
Bowmans Dam	202.4	7.97

24-HOUR RAINFALLS, 127 MILLIMETERS, 5 INCHES, OR MORE—*Continued*

	Mm.	Inches
Kentfield	220.2	8.66
Laurel	149.9	5.90
Mount	152.4	6.00
	142.5	5.61
	168.4	6.63
Brush Creek	130.3	5.13
Delta	127.2	5.01
	164.8	6.49
	133.4	5.25
Magalia	170.7	6.72
Mercury	138.9	5.47
	139.7	5.50
[illegible]	178.3	7.02
Bowmans Dam	131.6	5.18
Mount St. Helena	152.4	6.00
Upper Mattole	132.3	5.21
	198.1	7.80
	164.1	6.46
[illegible]	146.0	5.75
January, 1905—		
Helen Mine	221.5	8.72
Mount St. Helena	157.5	6.20
Upper Mattole	157.7	6.21
February, 1905—		
	135.4	5.33
March, 1905—		
Nordhoff	146.0	5.75
Glenn Ranch	141.7	5.58
Lowe Observatory	152.4	6.00
Nellie	149.9	5.90
Ozena	172.2	6.78
January, 1906—		
Helen Mine	245.1	9.65
Magalia	275.8	10.86
Stirling City	215.9	8.50
Blocksburg	157.2	6.19
Brush Creek	170.2	6.70
Branscomb	247.9	9.76
Delta	152.4	6.00
Fort Ross	139.4	5.49
Georgetown	127.0	5.00
Greenville	137.2	5.40
La Porte	155.7	6.13
Monumental	165.9	6.53
Nimshew	144.8	5.70

24-Hour Rainfalls, 127 Millimeters, 5 Inches, or More—*Continued*

	Mm.	Inches
Summerdale	180.3	7.10
Ukiah	132.1	5.20
Willits	195.6	7.70
Zenia	185.4	7.30
Bear Valley	129.0	5.08
Ben Lomond	131.6	5.18
[illegible]	150.6	[illegible]
	205.7	8.10
	165.1	6.50
Fouts Springs	127.2	5.01
Laurel	161.3	6.35
Laytonville	207.8	8.18
Mercury	172.7	6.80
Mount St. Helena	133.4	[illegible]
Nellie	158.5	6.24
Pilot Creek	187.7	7.39
Skyland	167.6	6.60
Upper Mattole	170.9	6.73
Woodleaf	174.0	6.85
March, 1906—		
Cuyamaca	190.0	7.48
Mono Ranch	292.1	11.50
Stirling City	132.1	5.20
Summerdale	154.4	[illegible]
Crockers	154.9	6.10
Glenn Ranch	166.9	6.57
Nellie	224.8	8.85
	135.4	5.33
Georgetown	149.4	5.88
Jamestown	139.7	5.50
Nevada City	140.0	5.51
Placerville	134.1	5.28
Sonora	137.7	5.42
Stirling City	152.4	6.00
Summit	127.0	5.00
Watsonville	132.1	5.20
Bear Valley	128.8	5.07
	179.8	7.08
	157.5	6.20
	130.0	5.12
	134.6	5.30
Glenwood	148.3	5.84
Grass Valley	141.0	5.55
Kennedy Mine	153.4	[illegible]
Laurel	143.5	5.65
Lowe Observatory	144.8	5.70

24-HOUR RAINFALLS, 127 MILLIMETERS, 5 INCHES, OR MORE—*Continued*

	Mm.	Inches
Lytle Creek	144.3	5.68
Mount St. Helena	127.0	5.00
January, 1907—		
Mono Ranch	150.4	5.92
Upper Mattole	220.0	8.66
February, 1907—		
Blue Cañon	141.0	5.55
Branscomb	139.7	5.50
Emigrant Gap	152.4	6.00
Fort Ross	152.2	5.99
	135.4	5.33
	132.1	5.20
Laytonville	144.0	5.67
March, 1907—		
Blocksburg	152.9	6.02
Blue Cañon	163.8	6.45
Branscomb	160.5	6.32
Brush Creek	144.8	5.70
Calistoga	142.2	5.60
Greenville	156.7	6.17
Healdsburg	135.4	5.34
Helen Mine	188.0	7.40
La Porte	185.2	7.29
Magalia	194.3	7.65
Mono Ranch	164.1	6.46
Nimshew	140.7	5.54
Quincy	165.1	6.50
Stirling City	200.7	7.90
[illegible]	145.5	5.74
Ben Lomond	152.9	6.02
	152.4	6.00
	136.9	5.39
Bowmans Dam	164.8	6.49
	141.7	5.58
	129.5	5.10
	150.9	5.94
Glenn Ranch	179.3	7.06
Inskip	203.2	8.00
Laurel	127.0	5.00
Laytonville	186.9	7.36
Lytle Creek	175.3	6.90
Mercury	137.2	5.40
Mount St. Helena	143.5	5.65
Upper Mattole	188.5	7.42
West Branch	189.7	7.47
Woodleaf	139.7	5.50

24-Hour Rainfalls, 127 Millimeters, 5 Inches, or More—*Continued*

	Mm.	Inches
December, 1907—		
Branscomb	133.4	5.25
Monumental	170.2	6.70
Ben Lomond	137.2	5.40
March, 1908—		
Cisco	182.9	7.20
October, 1908—		
Branscomb	151.9	5.98
January, 1909—		
Ben Lomond	138.4	5.45
Blue Cañon	182.9	7.20
Branscomb	218.4	8.60
Brush Creek	132.1	5.20
Camptonville	188.5	7.42
Cuyamaca	130.3	5.13
Deer Creek	206.5	8.13
Downieville	[illegible]	5.34
Fordyce Dam	191.3	7.53
Head Dam	165.9	6.53
Helen Mine	231.1	9.10
Inskip	167.1	6.58
Kennett	226.1	[illegible]
La Porte	[illegible]	9.16
Laytonville	[illegible]	[illegible]
Lick Observatory	161.8	6.37
Magalia	239.5	9.43
Mount St. Helena	168.9	6.65
Pilot Creek	232.7	9.16
Rialto	207.3	[illegible]
Santa Barbara	162.6	6.40
Sierra Madre	170.9	6.73
[illegible]	157.5	6.20
[illegible]	165.1	6.50
[illegible]le	[illegible]	[illegible]
Upland	151.6	5.97
Woodleaf	203.2	[illegible]
Georgetown	153.7	6.05
Grass Valley	161.3	6.35
Angels Camp	177.0	6.97
Bear River	136.1	5.36
Glenn Ranch	165.1	[illegible]
Julian	154.9	6.10
Lowe Observatory	199.1	7.84
Lionsville	169.4	6.67
Lytle Creek	245.9	9.68
Mesa Grande	165.1	6.50

24-HOUR RAINFALLS, 127 MILLIMETERS, 5 INCHES, OR MORE—*Concluded*

	Mm.	Inches
West Branch	188.7	7.43
Nellie	175.0	6.89
February, 1909—		
Cloverdale	136.6	5.38
Delta	175.0	6.89
Magalia	200.2	7.88
Mono Ranch	177.8	7.00
Santa Margarita	134.6	5.30
Sisson	198.9	7.83
Lytle Creek	131.1	5.16
March, 1909—		
Lytle Creek	140.2	5.52
November, 1909—		
Blue Cañon	127.0	5.00
Cisco	128.3	5.05
Monumental	243.8	9.60
December, 1909—		
Rialto	170.2	6.70
Santa Margarita	195.6	7.70
Summerdale	193.6	7.62
January, 1910—		
Lytle Creek	139.7	5.50
January, 1911—		
Branscomb	174.0	6.85
Brush Creek	152.9	6.02
Camptonville	159.3	6.27
Los Gatos	156.2	6.15
Magalia	172.7	6.80
Nevada City	154.9	6.10
Nimshew	134.1	5.28
Santa Barbara	129.3	5.09
Squirrel Inn	148.6	5.85
Summerdale	163.3	6.43
Ben Lomond	181.6	7.15
Glenn Ranch	159.5	6.28
Glenn Ranch	156.0	6.14
Laurel	190.5	7.50
Laytonville	173.5	6.83
Lick Observatory	233.4	9.19
Lick Observatory	141.2	5.56
West Branch	131.8	5.19
March, 1911—		
Mono Ranch	200.7	7.90
San Luis Obispo	151.9	5.98
Sierra Madre	130.6	5.14
Stirling City	148.6	5.85

In February, 1891, at Bear Valley Dam, from 6 p.m. of the 21st to 6 p.m. of the 22nd, 432 millimeters, 17 inches, fell, and in twenty-six hours 483 millimeters, 19 inches.

At Cuyamaca 594.4 millimeters, 23.40 inches, fell in fifty-four hours, of which 330 millimeters, 13 inches, fell in twenty-three hours, and seven inches in ten hours. The record by dates is as follows:

	Mm.	Inches
February 22	243.8	9.60
February 23	325.1	12.80
February 24	25.0	1.00

Heavy Rains in February, 1913

With one exception this was the driest February since 1904, taking the month and considering the state as a whole; but the precipitation was not uniformly distributed, and while some portions of the state showed an unusual deficiency other portions, particularly the counties south of the Tehachapi, had a rainfall that broke all records for 24-, 48-, and 72-hour periods. Furthermore, the distribution of the rain was not uniform, even in the south; for example, at Los Angeles the monthly amount was above 230 millimeters, 9 inches, or more than double the normal, while at San Diego the rainfall was slightly above the normal.

The month will probably be remembered for a long while to come in the southern counties because of the phenomenal rain beginning Sunday, February 23, and ending Wednesday, February 26. At Los Angeles on Sunday night and Monday morning there was a rainfall of 130.0 millimeters, 5.12 inches, which broke all records for 24-hour rainfall at that place. Not since December 19–20, 1879, had a rainfall of this character occurred. The records for 48-hour rainfall were broken at a number of places in the San Gabriel Valley. At Pasadena, 216.9 millimeters, 8.54 inches, fell; at Los Angeles, 178 millimeters, 7 inches; Pomona, 111.8 millimeters, 4.40 inches. The area of heaviest precipitation was from Point Conception to San Juan Point. At San Diego the precipitation was not as heavy as might have been expected. The storm was accompanied by heavy snow in the Sierra Madre,

the mountain ridges and 9 meters, 30 feet, deep in some of the cañons. Near the Pine Knot Hotel 1 meter, 3 feet, of snow fell in sixteen hours on February 21. This is said to be one of the heaviest snowfalls known in that vicinity.

SNOWFALL

Records have been kept at Summit, Placer County, elevation 2138 meters, 7017 feet, for nearly thirty-five years and the data are believed to constitute the longest and most reliable measurements of depth of snow that have been made. The conditions are remarkable also in that comparisons may be made on two sides of a high mountain range, the Sierra Nevada. It is well known that for a distance of nearly forty miles the Southern Pacific Railroad has erected snowsheds in order to maintain traffic during the winter months. The depth of the snow is also of direct importance to the many power companies, also to mining and irrigation. The problem of the conservation of snow and its dependence upon mountains and forest has been treated in detail by several writers, and more especially by Professor J. E. Church, Jr., of the University of Nevada. The water content of the snow, determined by weighing with a snow sampler devised by Church, permits quick surveys of large areas of snow, both on mountain tops and in the gulches, and in due time results will be forthcoming which will enable predictions of floods or insufficient water supply; also studies of stream flow and water resources. The writer had planned a study of the relation between total snowfall and depth on the ground which should give a curve characteristic of the season. Such a curve would in effect give a measure of the heat energy expended during a given period as determined by the rate of disappearance of the snow. The disturbing factor, however, is the wind action, and until we have some record of the direction and rate of flow of the air, and also of the load or absence of load of water vapor carried by the air stream, all forecasts of the probable water supply will be subject to error.

From the Summit records it will be noted that the annual snowfall has exceeded 19.68 meters, 775 inches, twice in a period

of thirty-five years. In the season 1879 to 1880 nearly 20 meters, 65 feet, fell. The least seasonal snowfall was 1880–81; or the season next after that of heaviest snowfall. The total amount was less than 4 meters, 153.5 inches. The average depth of the snow is nearly 11 meters, 36 feet.

Records of the depth of snow on the ground have been kept daily since 1898. Unfortunately the records previous to 1906 were destroyed by fire.

The snow problem is an ever-present one, always difficult to solve, and much remains to be done regarding proper methods of determining the water equivalent for given snow depths. The tables given below, however, are homogeneous and possess the merit of having been made at the one site and under one system for a period of thirty-five years. Within the last two years, owing to fire and removal of the station, the depth of snow has been measured at a point about 457 meters, 1500 feet, west. The data used since 1907 are the depths reported daily to the Weather Bureau office in San Francisco.

In the *Monthly Weather Review* for June, 1910, there was published an article on "Snowfall Records at Summit," giving the general facts regarding the records; also a discussion of the method used by Professor J. N. LeConte in 1908 for determining the mean rate of melting. It was found that the curves were extremely irregular for the eleven different seasons considered up to March 1, but fairly smooth after that date. Professor LeConte obtained an average curve showing the mean depth of snow on the ground at Summit. The curve is reproduced in figure 9. In many ways the period July 1, 1910, to June 30, 1911, was one of the most remarkable on record. It followed a season when there was less snow in the mountains than had been known for forty years. Up to January 9, 1911, the season was phenomenally dry and the snowfall a negligible quantity. Then there occurred a rapid change to the other extreme and the snow fell almost steadily until January 27, when there was approximately five meters, seventeen feet, on the ground. February was a month of moderate snowfall, also moderate melting. The total decrease was only 330 millimeters, 13 inches. During the first week in March 2286 millimeters, 90 inches, of snow were added.

Before the middle of the month a total depth of 7740 millimeters, 305 inches, was recorded. Then followed a long period of fair weather, permitting a rapid and nearly uniform rate of melting, the depth decreasing at the rate of about 203 millimeters, 8 inches, per day. It was noticeable, though, that the melting was less rapid as the depth decreased, although with the natural increase in the length of the day and the approach of warmer weather the contrary might have been expected. Without doubt the packing process plays an important part, and all measurements of depth and of melting must be corrected for this factor. The writer once made some approximate measurements of the water content of snow at the point under discussion. Samples of snow were taken from the top and the bottom of the snow bank, which had a depth of about 3.6 meters, 12 feet. Melting the samples, it was found that it required about 508 millimeters, twenty inches, of the loosely packed snow at the top to make thirty millimeters, one inch, of water, while of the more compact, almost slushy snow at the bottom it required only 102 millimeters, 4 inches, to make twenty-five millimeters, one inch, of water.

Fig. 9
Depth of snow at Summit. Solid line indicates average depth of snow, mean of 10 seasons Dotted line, depth of snow 1910–11. ABEFG, average rate of melting.

In the diagram (fig. 9) the dotted lines show the depth of snow on the ground for the season 1910–11. The solid line rep-

side we have the snowfall of the spring months. In the first groove there is inserted a card showing the mean rate of melting. This can be slid along in the groove and the rate compared with the profile of any given year. While this is not strictly the true rate of melting for the whole year, it affords an approximate measure of the rate of melting under normal conditions. Snowstorms are shown by peaks which indicate both the added depth and the rate of melting in the intervals of fair weather. At the right side of the frame vertical strips of cardboard show the total precipitation for the season and by suitable notches how much of the precipitation was snow. The whole design enables one to compare readily the depth of snow on the ground at any given date with the amount during previous seasons.

Summit is an interesting station for snowfall work, because 86 per cent of the precipitation falls in the form of snow, and most of the rain falls during July, August, and September, practically before the snow cover amounts to anything. It is true that occasionally there will come a warm rain in January or February, and such a condition rapidly reduces the depth of snow. The greatest factor, however, in reducing the depth is probably the wind. Under certain conditions, when the dry air moves rapidly from the northeast, decrease by evaporation becomes excessive. Two or three such days will lower the depth 200 millimeters, 8 inches, or more.

TOTAL PRECIPITATION, INCLUDING SNOW, AT SUMMIT, PLACER COUNTY, CALIFORNIA, FOR THE YEARS 1870 TO 1912

[Elevation, 7017 feet]

Seasons	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Year	Annual
1870–71	......	......	......	......	......	......	7.60	7.55	4.05	4.00	0.31	0.89	....	1871	60.60
1871–72	0.00	0.00	0.30	0.40	8.50	27.00	4.00	16.10	5.90	5.60	.30	.00	68.10	1872	37.90
1872–73	.00	.00	.00	.00	.00	6.00	2.31	16.20	6.05	2.55	2.11	.00	35.22	1873	40.95
1873–74	.03	T	.00	.00	.00	11.70	5.00	.00	.00	2.00	3.60	T	22.33	1874	18.85
1874–75	.00	.00	.00	3.80	3.60	.85	8.15	.12	4.80	.80	1.46	2.55	26.13	1875	*33.86
1875–76	T	.00	.00	*2.23	6.50	7.25	14.65	8.70	13.80	2.60	1.60	T	*57.33	1876	46.90
1876–77	1.21	.10	.56	2.98	.50	.20	8.90	.69	3.44	4.84	3.75	.12	27.29	1877	26.73
1877–78	.00	.00	.30	.55	3.34	.80	10.00	11.50	3.05	2.40	1.60	.00	33.54	1878	32.69
1878–79	.00	.09	.44	1.21	.80	1.60	13.65	8.70	21.05	4.52	2.55	.10	54.71	1879	73.67
1879–80	.00	T	.00	4.20	5.60	13.30	6.60	7.50	8.90	30.40	3.60	.00	80.10	1880	64.50
1880–81	.80	.00	.00	.00	.50	6.20	7.50	4.60	1.50	1.00	.05	.50	22.65	1881	30.95
1881–82	.00	.00	.60	3.10	3.05	9.05	7.40	9.00	19.30	3.25	.60	.00	55.35	1882	62.12
1882–83	.00	.00	.75	12.95	3.95	4.92	1.00	2.60	7.70	3.40	3.42	.00	40.69	1883	23.57
1883–84	.00	.00	.10	.95	1.20	3.20	7.60	12.70	9.10	12.60	.80	4.04	52.29	1884	60.47
1884–85	.00	.00	1.10	3.13	.00	9.40	1.40	.58	.10	4.88	1.00	.80	22.39	1885	25.41
1885–86	.00	T	.05	.00	13.60	3.00	13.90	1.40	7.80	6.40	.95	.00	47.10	1886	41.00
1886–87	.00	.00	.00	3.10	1.70	5.75	6.25	20.70	1.40	5.80	.95	1.60	47.25	1887	49.97
1887–88	.10	T	T	.07	1.50	11.60	9.20	1.29	8.05	2.30	1.04	3.72	38.87	1888	36.55
1888–89	3.51	.28	.00	.00	1.90	5.26	1.00	1.50	9.55	1.90	6.30	.22	31.42	1889	51.42
1889–90	.00	.00	.00	5.65	6.80	18.50	19.20	11.60	14.00	2.60	.25	.00	78.60	1890	55.05

* Partly interpolated.

TOTAL PRECIPITATION, INCLUDING SNOW, AT SUMMIT, PLACER COUNTY, CALIFORNIA, FOR THE YEARS 1870 TO 1912—*Continued*

[Elevation, 7017 feet]

Seasons	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Year	Annual
1890–91	.00	.00	.00	.00	.00	7.40	1.50	13.80	5.10	4.60	1.10	.00	33.55	1891	*38.55
1891–92	.00	.00	*.20	.05	.30	11.90	4.00	3.40	7.40	4.50	6.30	.20	*38.25	1892	44.70
1892–93	.00	.00	.00	.60	8.80	9.50	7.90	10.80	14.50	9.20	.00	.00	61.30	1893	52.30
1893–94	.00	.00	.00	.30	3.60	6.00	15.50	5.25	3.40	4.30	2.40	.00	50.75	1894	69.75
1894–95	.00	.00	.50	2.90	1.00	24.50	25.80	4.20	4.70	2.50	2.40	.00	68.50	1895	49.50
1895–96	.00	.00	.20	.00	1.40	8.30	10.50	.70	9.70	18.20	5.40	.00	54.40	1896	*62.43
1896–97	*.21	*.02	.40	.90	12.30	4.10	4.05	14.35	18.00	1.25	.00	.70	*56.28	1897	47.73
1897–98	.00	.00	.03	2.50	2.65	4.20	4.00	7.10	5.20	.80	2.90	.90	31.28	1898	31.40
1898–99	.00	.00	.00	4.40	2.50	3.60	12.70	5.20	15.75	1.75	3.60	.70	50.20	1899	73.80
1899–1900	.00	1.00	.00	16.05	9.15	7.90	5.25	4.75	8.15	4.80	3.97	.50	61.52	1900	42.52
1900–01	.25	T	.95	3.50	6.90	3.50	11.30	14.20	4.50	5.50	1.00	.00	51.60	1901	49.60
1901–02	.00	.00	1.40	4.20	4.70	2.80	4.00	16.30	8.90	3.00	1.10	.30	46.70	1902	49.00
1902–03	.00	1.00	.00	2.30	7.50	4.60	10.50	3.20	11.10	1.70	.80	T	42.70	1903	40.50
1903–04	.00	.00	.00	1.20	11.20	.80	4.20	30.40	21.30	3.90	.23	.05	73.28	1904	76.54
1904–05	.04	.03	4.56	1.90	1.33	8.60	5.55	7.00	10.70	2.90	3.70	1.40	47.71	1905	43.85
1905–06	T	.00	.50	.60	7.80	3.70	14.10	9.30	11.75	2.60	4.12	2.10	56.57	1906	57.55
1906–07	T	1.00	.32	.12	2.04	10.10	13.50	4.38	27.36	2.66	3.06	2.22	66.76	1907	66.48
1907–08	.12	T	.06	2.52	.40	10.20	3.50	4.50	10.20	1.14	3.70	.44	36.78	1908	33.28
1908–09	.00	.75	1.20	1.54	3.60	2.70	29.44	8.94	4.60	.40	1.10	.88	55.16	1909	*60.62
1909–10	.00	.00	.72	1.66	*4.58	8.30	8.60	5.10	4.98	.68	.53	.00	35.15	1910	33.91
1910–11	1.16	.00	2.82	.50	5.46	4.08	28.90	5.30	10.63	4.70	1.52	.04	65.11	1911	60.56
1911–12	.00	.00	.25	.60	2.02	6.60	3.24	.46	6.10	3.50	1.88	.20	24.85	1912	26.59
Mean	.19	.11	.45	2.30	4.01	7.31	9.27	8.08	8.96	4.51	2.08	.61	47.37	....	47.12

* Partly interpolated.

SNOWFALL AT SUMMIT, PLACER COUNTY, CALIFORNIA, FOR THE YEARS 1878 TO 1912

[Elevation, 7017 feet]

Years	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Annual
1878	......	......	......	......	....	....	100.0	115.0	30.0	24.0	16.0	......	....
1878–79	......	......	4.2	12.1	8.0	6.0	77.5	57.0	209.0	45.2	25.5	1.0	445.5
1879–80	......	T	.0	42.0	56.0	133.0	66.0	75.0	89.0	298.0	24.0	......	783.0
1880–81	......	......	......	......	5.0	62.0	45.0	16.0	15.0	10.0	.5	......	153.5
1881–82	......	......	6.0	26.0	30.5	43.0	65.5	90.0	193.0	32.5	6.0	......	492.5
1882–83	......	......	7.5	27.5	39.5	49.5	10.0	26.0	72.0	34.0	33.0	......	299.0
1883–84	......	......	......	9.5	12.0	32.0	76.0	127.0	91.0	126.0	2.0	6.0	481.5
1884–85	......	......	11.0	21.0	.0	94.0	14.0	5.0	1.0	38.0	10.0	8.0	202.0
1885–86	.....	......	......	......	136.0	30.0	131.0	14.0	78.0	64.0	9.5	......	462.5
1886–87	.....	......	......	31.0	17.0	34.0	56.0	207.0	14.0	58.0	5.0	......	422.0
1887–88	......	......	......	T	15.0	116.0	92.0	7.0	80.5	21.0	4.0	9.5	345.0
1888–89	......	......	......	......	16.5	39.0	10.0	15.0	95.5	19.0	63.0	3.0	261.0
1889–90	......	......	......	24.0	61.0	185.0	192.0	116.0	147.0	26.0	25.0	......	776.0
1890–91	......	......	......	......	....	74.0	15.0	138.0	51.0	46.0	11.0	......	335.0
1891–92	......	......	......	.5	3.0	119.0	40.0	34.0	74.0	45.0	63.0	2.0	380.5
1892–93	......	......	......	6.0	88.0	95.0	79.0	108.0	145.0	92.0	21.0	......	634.0
1893–94	......	......	3.5	3.0	36.0	60.0	155.0	152.5	34.0	43.0	24.0	......	511.0
1894–95	......	......	5.0	29.0	10.0	245.0	258.0	42.0	47.0	25.0	24.0	......	685.0
1895–96	......	......	2.0	.0	14.0	83.0	105.0	7.0	97.0	182.0	54.0	......	544.0
1896–97	......	......	4.0	9.0	123.0	41.0	40.5	143.5	180.0	12.5	.0	7.0	560.5

SNOWFALL AT SUMMIT, PLACER COUNTY, CALIFORNIA, FOR THE YEARS 1878 TO 1912—*Continued*

[Elevation, 7017 feet]

Years	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Annual
1897–98	......	......	.5	25.0	26.5	42.0	40.0	30.0	52.0	8.0	29.0	9.0	262.0
1898–99	......	......	......	34.0	25.0	36.0	127.0	52.0	157.5	17.5	32.0	......	481.0
1899–1900	......	......	......	89.0	29.0	79.0	41.0	38.0	79.0	42.0	9.0	......	406.0
1900–01	......	......	1.5	21.0	60.0	15.0	113.0	120.0	45.0	55.0	10.0	......	440.5
1901–02	......	......	14.0	22.0	12.0	10.0	19.0	163.0	89.0	30.0	11.0	3.0	373.0
1902–03	......	......	......	23.0	75.0	46.0	85.0	32.0	111.0	27.0	8.0	......	407.0
1903–04	......	......	......	1.0	22.0	8.0	42.0	172.0	148.0	39.0	2.0	......	434.0
1904–05	......	......	3.0	14.0	12.0	66.0	50.0	64.0	107.0	23.0	34.0	2.0	375.0
1905–06	......	......	5.0	.0	78.0	37.0	138.0	82.0	109.0	26.0	36.0	3.0	514.0
1906–07	......	......	......	T	18.0	98.5	136.0	26.0	265.0	21.0	19.0	19.0	602.0
1907–08	......	......	T	3.0	4.0	101.0	35.0	45.0	102.0	12.0	37.0	1.0	340.0
1908–09	......	......	T	10.0	36.0	27.0	226.0	82.0	46.0	4.0	11.0	......	442.0
1909–10	......	......	......	9.0	59.0	83.0	86.0	51.0	42.0	8.0	4.0	......	342.0
1910–11	......	......	......	3.0	30.0	33.0	283.0	53.0	99.0	....	......	......	524.0
1911–12	......	......	T	3.0	20.0	66.0	70.0	3.0	61.0	35.0	18.0	1.0	....
Mean	......	......	2.1	15.0	35.1	67.3	89.7	73.7	94.0	47.1	20.1	2.3	443.5

Depth of Snow on Ground in Inches at Summit, Placer County, California, for the Years 1907 to 1913

[Records for the year 1906 destroyed by fire April 18, 1906]

Day of month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1907												
1	45	137	104	240	115	68	14	*	*	......	......	......
3	63	127	115	230	113	60	12	......	*	......	*	......
5	80	120	123	230	114	51	11	*	......	......	......	6
7	83	115	127	216	114	43	9	*	......	......	......	24
9	86	110	131	195	113	39	7	*	*	......	......	25
11	82	103	176	175	113	48	4	......	*	......	......	38
13	103	95	198	155	123	54	2	......	*	......	......	47
15	142	88	191	165	121	50	*	......	......	......	......	......
17	153	86	171	157	118	46	†	......	......	......	4	......
19	158	84	206	145	112	41	*	......	*	......	4	......
21	152	84	246	134	110	38	*	......	......	......	4	......
23	147	83	......	125	......	35	*	......	......	......	4	......
25	148	90	301	122	......	29	......	......	......	......	3	......
27	145	91	305	119	89	25	*	......	......	†	......	......
29	143	88	294	117	81	16	*	*	T	......	......	......
31	148	......	262	......	71	......	*	......	......	1	......	......
1908												
1	87	88	116	50	20	13	......	......	......	......	2	24
3	85	109	155	50	28	13	......	......	......	......	2	31
5	83	114	171	45	26	12	......	......	......	......	1	37
7	81	114	176	45	27	11	......	......	......	......	......	34
9	77	117	170	41	29	6	......	......	......	......	......	32
11	72	115	152	35	31	*	......	......	......	......	......	30
13	73	115	140	31	30	......	......	......	......	......	......	30
15	72	112	130	31	42	......	......	......	......	3	......	32
17	73	110	118	32	45	......	......	......	......	4	......	30
19	78	107	110	28	52	......	......	......	......	7	......	34
21	91	101	99	27	48	......	......	......	......	5	4	29
23	87	91	91	32	40	......	......	......	......	4	31	34
25	94	81	80	31	33	......	......	......	......	3	37	29
27	91	71	74	28	25	......	......	......	......	3	36	25
29	87	78	67	23	20	......	......	......	......	2	32	23
31	87	......	60	......	16	......	......	......	......	2	......	21
1909												
1	28	172	201	188	119	27	......	......	......	......	......	2
3	45	177	......	179	102	20	......	......	......	......	......	11
5	30	178	210	177	87	14	......	......	......	......	0	25
7	59	196	223	173	78	8	......	......	......	......	8	32
9	127	209	215	169	68	6	......	......	......	......	12	72
11	121	208	213	168	65	6	......	......	......	......	31	42

* Several feet of snow in cañons.

† Several feet of snow on highest peaks.

DEPTH OF SNOW ON GROUND IN INCHES AT SUMMIT, PLACER COUNTY, CALIFORNIA, FOR THE YEARS 1907 TO 1913—*Continued*

Day of month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
13	127	224	205	155	67	5	......	......	......	......	36	28
15	99	220	196	158	66	4	......	......	......	......	47	24
17	89	202	189	152	64	3	......	......	......	......	25	22
19	89	207	191	152	55	2	......	......	......	......	25	21
21	110	216	......	148	51	1	......	......	......	......	25	26
23	140	213	199	144	53	0	......	......	......	......	7	37
25	162	218	197	138	48	......	......	......	......	......	12	36
27	169	213	198	133	42	......	......	......	......	......	7	36
29	168	......	205	129	40	......	......	......	......	......	4	......
31	172	......	191	......	33	......	......	......	......	......	......	45
1910												
1	54	76	65	65	13	2	......	......	......	......	......	7
3	60	72	50	57	16	2	......	......	......	......	......	24
5	65	67	44	55	16	1	......	......	......	......	......	20
7	64	77	40	49	14	......	......	......	......	......	......	20
9	67	83	40	47	12	......	......	......	......	......	.5	8
11	64	81	39	48	12	......	......	......	......	......	.5	......
13	62	70	38	47	11	......	......	......	......	......	5.0	6
15	87	75	38	32	12	......	......	......	......	......	3.0	4
17	108	64	37	29	10	......	......	......	......	......	2.0	4
19	103	72	38	23	9	......	......	......	......	......	7.0	6
21	96	70	62	19	9	......	......	......	......	......	4.0	6
23	84	78	70	15	8	......	......	......	......	......	2.0	5
25	105	88	75	13	6	......	......	......	......	......	19.0	4
27	84	84	78	12	6	......	......	......	......	......	15.0	4
29	74	72	73	12	4	......	......	......	......	......	9.0	4
31	68	......	68	......	3	......	......	......	......	......	......	4
1911												
1	4	228	222	135	94	38	......	......	......	......	......	1
3	4	230	242	122	90	31	......	......	......	......	......	1
5	4	232	264	140	85	28	......	......	......	T	......	1
7	3	238	285	140	85	22	......	......	......	......	......	3
9	15	219	305	154	78	10	......	......	......	1	1	2
11	41	219	305	151	72	6	......	......	......	......	12	2
13	108	235	290	153	76	T	......	......	......	......	12	2
15	126	240	276	146	65	......	......	......	......	......	16	2
17	123	238	252	135	68	......	......	......	......	......	10	14
19	130	225	230	128	66	......	......	......	......	......	5	11
21	157	215	208	120	57	......	......	......	......	......	5	10
23	147	212	184	108	50	......	......	......	......	......	3	12
25	182	215	167	100	47	......	......	......	......	......	2	16
27	202	215	159	98	45	......	......	......	......	......	2	23
29	156	......	150	96	42	......	......	......	......	......	2	52
31	218	......	138	......	37	......	......	......	......	......	......	56

DEPTH OF SNOW ON GROUND IN INCHES AT SUMMIT, PLACER COUNTY, CALIFORNIA, FOR THE YEARS 1907 TO 1913—*Continued*

Day of month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1912												
1	60	38	26	50	36	5	......	......	......	......	......	T
3	58	36	34	43	36	3	......	......	......	......	......	‖
5	55	32	40	38	33	2	......	......	......	......	......	‖
7	57	31	62	32	30	T	......	......	......	......	......	‖
9	63	29	61	28	24	‖	......	......	......	......	......	‖
11	75	28	60	39	18	‖	......	......	......	......	......	‖
13	58	27	74	39	16	‖	......	......	......	......	......	‖
15	46	27	81	30	13	‖	......	......	......	......	......	13
17	48	26	79	24	9	‖	......	......	......	......	......	21
19	51	25	77	24	7	‖	......	......	......	......	......	18
21	40	25	76	21	18	‖	......	......	......	......	......	18
23	35	26	71	18	18	1	......	......	......	......	......	17
25	30	26	65	19	14	......	......	......	......	......	......	17
27	54	25	59	16	10	......	......	......	......	......	......	15
29	45	23	57	29	......	......	......	......	......	......	......	12
31	41	......	53	......	......	......	......	......	......	......	......	17
1913												
1	17	85	52	50	23	......	......	......	......	......	......	31
3	11	81	50	51	18	......	......	......	......	......	......	30
5	11	78	47	52	11	......	......	......	......	......	......	28
7	11	72	46	50	5	......	......	......	......	......	......	24
9	25	65	45	46	2	......	......	......	......	......	......	20
11	25	60	44	41	T	......	......	......	......	......	18	21
13	32	57	43	38	‖	......	......	......	......	......	17	24
15	72	55	42	41	‖	......	......	......	......	......	15	24
17	125	52	41	39	‖	......	......	......	......	......	13	27
19	137‡	52	50	40	‖	......	......	......	......	......	16	28
21	134	55	61	35	‖	......	......	......	......	......	21	32
23	128	54	68	33	‖	......	......	......	......	......	17	58
25	114	57	67	28	‖	......	......	......	......	......	22	92
27	104	59	63	24	‖	......	......	......	......	......	29	91
29	97	......	59	24	‖	......	......	......	......	......	30	93
31	88	......	50	......	......	......	......	......	......	......	......	80

‖ Snow in patches.
‡ 141 on the 18th.

Seasonal Snowfall in Inches

Bishop Creek, Inyo County, California

[Elevation, 8500 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1909–10	......	......	......	......	18.0	65.2	36.0	4.5	5.0	9.5	......	......	138.2
1910–11	......	......	......	25.0	1.0	34.5	91.0	29.0	88.5	5.0	17.5	......	291.5
1911–12	......	......	......	2.0	10.0	13.0	8.0	0	30.0	37.0	16.0	6.0	122.0

Crockers, Tuolumne County, California

[Elevation, 4452 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1906–07	......	......	......	......	......	11.5	90.0	0	70.0	T	T	......	171.5
1907–08	......	......	......	......	......	9.0	12.0	16.0	32.0	0	7.0	......	76.0
1908–09	......	......	......	......	3.5	9.0	34.0	33.5	25.0	......	......	......	105.0
1909–10	......	......	......	T	10.0	20.0	50.0	6.0	14.5	......	......	......	100.5

Glennville (near), Kern County, California

[Elevation, 5500 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1909–10	......	......	......	......	17.0	19.0	18.0	7.0	13.5	5.0	......	......	79.5
1910–11	......	......	......	T	T	8.0	3.0	22.0	7.0	......	......	......	40.0
1911–12	......	......	......	......	T	10.0	T	T	2.0	6.0	......	......	18.0

Hetch Hetchy, Tuolumne County, California

[Elevation, 3665 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1910–11	......	......	......	......	1.5	0	9.2	18.0	8.0	T	T	......	36.7
1911–12	......	......	......	T	0	20.5	6.5	T	12.0	6.0	T	......	45.0

SEASONAL SNOWFALL IN INCHES—*Continued*

Lake Eleanor, Tuolumne County, California

[Elevation, 4700 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1909–10	......	......	......	......	24.0	25.8	67.0	25.5	19.0	2.0	......	......	163.3
1910–11	......	......	......	6.0	7.0	T	65.0	53.0	72.0	10.0	3.0	......	210.0
1911–12	......	......	......	......	1.5	42.5	21.0	0	56.0	29.5	1.0	......	151.5

Summerdale, Mariposa County, California

[Elevation, 5270 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1895–96	......	......	......	......	......	......	4.0	4.0	29.0	32.0	5.0	......	....
1896–97	......	......	......	6.0	3.0	18.0	24.0	41.0	83.0	5.0	......	......	180.0
1897–98	......	......	......	1.0	0	14.0	18.0	9.0	27.0	......	......	......	69.0
1898–99	......	......	......	2.0	4.0	1.0	41.0	14.0	45.0	......	......	......	107.0
1899–1900	......	......	......	32.0	8.0	14.0	0	2.0	34.0	17.0	......	......	107.0
1900–01	......	T	0	0	38.0	3.0	20.0	75.0	17.0	7.0	4.0	......	164.0
1901–02	......	......	1.0	3.0	6.0	1.0	11.0	38.0	33.0	12.0	2.0	1.0	108.0
1902–03	......	......	......	......	10.0	7.0	30.0	37.0	43.0	10.0	3.0	......	140.0
1903–04	......	......	......	......	......	4.0	22.0	44.0	54.0	17.0	3.0	......	144.0
1904–05	......	......	......	......	......	16.0	4.0	14.0	18.0	4.0	18.0	......	74.0

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1905–06	......	......	......	......	33.0	15.0	26.0	25.0	78.0	17.0	12.0	......	206.0
1906–07	......	......	......	T	3.0	44.0	99.0	8.0	84.0	1.0	0	1.0	240.0
1907–08	......	......	......	......	1.0	26.0	30.0	49.0	......	11.0	6.0	......	....
1908–09	......	......	......	......	6.0	17.0	56.0	57.0	33.0	1.0	......	......	170.0
1909–10	......	......	......	1.0	29.0	30.0	52.0	6.0	17.0	1.8	......	......	136.0
1910–11	......	......	......	7.0	5.0	0	57.0	......	......	......	5.0	......	....
1911–12	......	......	......	......	......	39.0	22.0	......	......	......	......	......	....

SEASONAL SNOWFALL IN INCHES—*Concluded*

Tamarack, Alpine County, California

[Elevation, 8000 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1906	......	......	......	......	......	......	168.5	90.0	218.0	28.0	50.0	5.5	....
1906–07	......	......	2.5	4.0	82.5	198.0	139.0	30.0	314.0	15.0	47.0	52.0	884.0
1907–08	......	T	1.0	3.5	4.0	97.0	89.0	75.0	59.0	2.0	64.5	......	395.0
1908–09	......	......	1.0	21.0	34.0	26.0	251.0	117.0	41.0	10.0	12.0	2.0	515.0
1909–10	......	......	1.0	31.0	116.0	92.0	97.0	46.0	31.0	5.0	14.0	......	433.0
1910–11	......	......	......	13.0	34.0	62.0	390.0	136.0	73.0	51.0	11.0	......	757.0
1911–12	......	......	2.0	14.5	36.5	62.0	47.0	6.0	61.0	80.0	35.0	4.0	348.0

Yosemite, Mariposa County, California

[Elevation, 3945 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1906–07	......	......	......	......	1.0	35.5	97.5	1.0	57.5	......	......	......	192.5
1907–08	......	......	......	......	T	20.0	10.0	9.0	17.0	0	0.2	......	56.2
1908–09	......	......	......	0.2	10.5	5.0	51.0	79.5	22.0	......	......	......	168.2
1909–10	......	......	......	......	26.0	22.5	43.0	21.0	7.0	0	0.5	......	120.0
1910–11	......	......	......	0.5	0	0	9.8	20.3	29.0	......	......	......	59.6
1911–12	......	......	......	......	......	23.0	10.0	0	12.0	21.0	......	......	66.0

Springville, Tulare County, California

[Elevation, 4000 feet]

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Season
1907–08	......	......	......	......	......	4.0	10.0	45.0	10.0	......	......	......	69.0
1908–09	......	......	......	......	6.0	13.0	15.0	29.0	35.5	......	......	......	98.5
1909–10	......	......	......	......	14.0	26.0	49.0	18.0	6.0	......	......	......	113.0
1910–11	......	......	......	......	2.0	T	0	T	T	......	......	......	2.0
1911–12	......	......	......	......	......	33.0	7.0	2.0	40.0	24.0	......	......	106.0

Seasonal Rainfalls

San Francisco	Mm.	Inches
From 1849–59, 10 seasons	5,777	227.47
From 1859–69, 10 seasons	6,549	257.85
From 1869–79, 10 seasons	5,766	227.00
From 1879–89, 10 seasons	5,950	234.23
From 1889–99, 10 seasons	5,558	218.81
From 1899–1909, 10 seasons	5,341	210.28
60-year mean	582	22.93

Sacramento	Mm.	Inches
From 1849–59, 10 seasons	4,800	188.97
From 1859–69, 10 seasons	5,308	208.97
From 1869–79, 10 seasons	4,539	178.70
From 1879–89, 10 seasons	5,252	206.77
From 1889–99, 10 seasons	4,961	195.30
From 1899–1909, 10 seasons	4,910	193.30
60-year mean	496	19.53

Fresno	Mm.	Inches
From 1881–88, 8 seasons	2,105	84.99
From 1888–98, 10 seasons	2,407	97.09
From 1898–1908, 10 seasons	2,208	89.81
28-year mean	241	9.71

Eureka	Mm.	Inches
From 1889–99, 10 seasons	12,000	472.36
From 1899–1909, 10 seasons	11,095	468.66
20-year mean	1,195	47.05

Los Angeles	Mm.	Inches
From 1878–88, 10 seasons	4,190	164.95
From 1888–98, 10 seasons	4,086	160.88
From 1898–1908, 10 seasons	3,495	137.62
30-year mean	393	15.45

San Diego	Mm.	Inches
From 1850–59, 9½ seasons	2,055	81.05
From 1859–69, 10 seasons	2,467	97.04
From 1869–79, 10 seasons	2,153	84.71
From 1879–89, 10 seasons	3,030	119.21
From 1889–99, 10 seasons	2,205	88.54
From 1899–1909, 10 seasons	2,468	97.14
59½-year mean	243	9.54

Red Bluff	Mm.	Inches
From 1879–89, 10 seasons	5,820	229.12
From 1889–99, 10 seasons	6,520	255.98
From 1899–1909, 10 seasons	7,184	282.83
30-year mean	650	25.60

SAN FRANCISCO RAINFALL

Rainfall records have been maintained in San Francisco for a period of sixty-four years. The greatest 24-hour rainfall occurred on January 28, 1881, when 118.6 millimeters, 4.67 inches, fell. The next greatest 24-hour rainfall was on September 24, 1904, when 909 millimeters, 3.58 inches, fell. A detailed statement of excessive rains will be found elsewhere. The longest rainless period was in 1903, when no rain fell from April 16 until October 9, 175 days. In 1911 there was no rain from June 6 to October 1, 116 days.

Fig. 11
Annual rainfall at San Francisco, 1850–1911
Cut from U. S. Wea. Bureau Bull. 44, Washington, 1913

Some of the months of heaviest rain were January, 1862, when 618.8 millimeters, 24.36 inches, of rain fell, and 18 days of the month were rainy. In January, 1911, 350.3 millimeters, 13.79 inches, fell, distributed over 18 days. In January, 1909, 267.0 millimeters, 10.51 inches, fell, but there were 26 rainy days, making it in this sense the rainiest month known at San Francisco. In January, 1890, 244.1 millimeters, 9.61 inches, fell, and

San Francisco Rainfall, Monthly, Seasonal, and Annual, 1849–1913

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Year	Annual
1849–50	0	0	0	3.14	8.66	6.20	8.34	1.77	4.53	0.46	0	0	33.10	1850	17.40
1850–51	0	0	0.33	0	0.92	1.05	0.72	0.54	1.94	1.23	0.67	0.02	7.42	1851	15.60
1851–52	0	0.02	1.03	0.21	2.12	7.10	0.58	0.14	6.68	0.26	0.32	0	18.46	1852	27.29
1852–53	0	0	0	0.80	5.31	13.20	3.92	1.42	4.86	5.37	0.38	0	35.26	1853	21.17
1853–54	0	0.04	0.46	0.12	2.28	2.32	3.88	8.04	3.51	3.12	0.02	0.08	23.87	1854	22.45
1854–55	0	0.01	0.15	2.43	0.34	0.87	3.67	4.77	4.64	5.00	1.88	0	23.76	1855	26.39
1855–56	0	0	0	0	0.67	5.76	9.40	0.50	1.60	2.94	0.76	0.03	21.66	1856	22.31
1856–57	0.02	0	0.07	0.45	2.79	3.75	2.45	8.59	1.62	0	0.05	0.12	19.91	1857	20.96
1857–58	0	0.05	0	0.93	3.01	4.14	4.36	1.83	5.55	1.55	0.34	0.05	21.81	1858	23.46
1858–59	0.05	0.16	0	2.74	0.69	6.14	1.28	6.32	3.02	0.27	1.55	0	22.22	1859	21.39
1859–60	0	0.02	0.03	0.05	7.28	1.57	1.64	1.60	3.99	3.14	2.86	0.09	22.27	1860	21.18
1860–61	0.21	0	0	0.91	0.58	6.16	2.47	3.72	4.08	0.51	1.00	0.08	19.72	1861	25.52
1861–62	0	0	0.02	0	4.10	9.54	24.36	7.53	2.20	0.73	0.74	0.05	49.27	1862	38.63
1862–63	0	0	0	0.52	0.15	2.35	3.63	3.19	2.06	1.61	0.23	0	13.74	1863	15.10
1863–64	0	0	0.03	0	2.55	1.80	1.83	0	1.52	1.57	0.78	0	10.08	1864	21.64
1864–65	0	0.21	0.01	0.13	6.68	8.91	5.14	1.34	0.74	0.94	0.63	0	24.73	1865	14.06
1865–66	0	0	0.24	0.26	4.19	0.58	10.88	2.12	3.04	0.12	1.46	0.04	22.93	1866	36.28
1866–67	0	0	0.11	0	3.35	15.16	5.16	7.20	1.58	2.36	0	0	34.92	1867	30.64
1867–68	0	0	0.04	0.20	3.41	10.69	9.50	6.13	6.30	2.31	0.03	0.23	38.84	1868	30.17
1868–69	0	0	0	0.15	1.18	4.34	6.35	3.90	3.14	2.19	0.08	0.02	21.35	1869	22.59
1869–70	0	0	0.12	1.29	1.19	4.31	3.89	4.78	2.00	1.53	0.20	0	19.31	1870	16.24
1870–71	0	0	0.03	0	0.43	3.38	3.07	3.76	1.05	1.89	0.23	0.01	14.11	1871	27.53
1871–72	0	0.02	0	0.07	2.81	14.36	4.03	6.90	1.59	0.81	0.18	0.04	30.78	1872	22.42
1872–73	0.01	0	0.04	0.11	2.79	5.95	1.58	3.94	0.78	0.43	0	0.02	15.66	1873	18.56
1873–74	0.01	0.08	0	0.83	1.16	9.72	5.66	2.21	3.36	0.90	0.66	0.14	24.73	1874	22.52

SAN FRANCISCO RAINFALL, MONTHLY, SEASONAL, AND ANNUAL, 1849–1913—*Continued*

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Year	Annual
1874–75	0	0	0.02	2.69	6.55	0.33	8.01	0.32	1.30	0.10	0.22	1.02	20.56	1875	22.63
1875–76	0	0	0	0.24	7.27	4.15	7.55	4.92	5.49	1.29	0.24	0.04	31.19	1876	23.54
1876–77	0.01	0.01	0.38	3.36	0.25	0	4.32	1.18	1.08	0.26	0.18	0.01	11.04	1877	11.93
1877–78	0.02	0	0	0.65	1.57	2.66	11.97	12.52	4.56	1.06	0.16	0.01	35.18	1878	33.26
1878–79	0.01	T	0.55	1.27	0.57	0.58	3.52	4.90	8.75	1.89	2.35	0.05	24.44	1879	30.76
1879–80	0.01	0.02	T	0.78	4.03	4.46	2.23	1.87	2.08	10.06	1.12	0	26.66	1880	30.07
1880–81	0	0	0	0.05	0.33	12.33	8.69	4.65	0.90	2.00	0.22	0.69	29.86	1881	23.73
1881–82	0	0	0.25	0.54	1.94	3.85	1.68	2.96	3.45	1.22	0.21	0.04	16.14	1882	18.67
1882–83	0	0	0.26	2.66	4.18	2.01	1.92	1.04	3.01	1.51	3.52	0.01	20.12	1883	15.43
1883–84	0	0	0.42	1.48	1.60	0.92	3.94	6.65	8.24	6.33	0.23	2.57	32.38	1884	38.82
1884–85	T	0.04	0.33	2.55	0.26	7.68	2.53	0.30	1.01	3.17	0.04	0.19	18.10	1885	24.90
1885–86	0.06	T	0.11	0.72	11.78	4.99	7.42	0.24	2.07	5.28	0.37	0.01	33.05	1886	20.02
1886–87	0.23	T	0.01	1.48	0.84	2.07	1.90	9.24	0.84	2.30	0.06	0.07	19.04	1887	19.04
1887–88	T	0.01	0.29	T	0.99	3.34	6.81	0.94	3.60	0.11	0.38	0.27	16.74	1888	23.03
1888–89	0.01	0.01	0.98	0.13	3.99	5.80	1.28	0.72	7.78	0.96	2.17	0.03	23.86	1889	36.94
1889–90	0.01	T	T	7.28	2.90	13.81	9.61	5.16	4.73	1.18	1.07	0.10	45.85	1890	25.43
1890–91	0.02	0	0.31	0	0	3.25	0.98	7.26	1.96	2.44	1:25	0.11	17.58	1891	21.11
1891–92	0.10	0.02	0.77	0.04	0.56	5.62	2.42	2.90	2.85	1.39	1.86	T	18.53	1892	22.08
1892–93	0	0	0.02	1.65	3.91	5.08	3.05	2.75	4.08	1.03	0.15	0.03	21.75	1893	17.91
1893–94	0.02	0	0.21	0.16	4.18	2.25	5.99	2.69	0.60	0.50	1.31	0.56	18.47	1894	24.32
1894–95	T	0	1.05	1.73	0.88	9.01	6.99	2.31	1.89	1.24	0.60	0	25.70	1895	17.13
1895–96	0.01	0	0.77	0.11	1.78	1.43	8.14	0.28	2.85	5.16	0.72	0	21.25	1896	28.25
1896–97	0.04	0.09	0.52	1.55	4.56	4.34	2.26	4.41	4.56	0.27	0.61	0.22	23.43	1897	16.40
1897–98	T	T	0.10	1.70	1.05	1.22	1.12	2.13	0.24	0.19	1.44	0.19	9.38	1898	9.31
1898–99	0	T	1.06	0.86	0.46	1.62	3.67	0.10	7.61	0.62	0.86	0.01	16.87	1899	23.23

San Francisco Rainfall, Monthly, Seasonal, and Annual, 1849–1913—*Continued*

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Year	Annual
1899–1900	0	T	0	3.92	3.79	2.65	4.11	0.64	1.91	1.08	0.32	0.05	18.47	1900	15.33
1900–01	T	T	0.46	1.48	3.91	1.37	5.79	5.03	0.80	1.64	0.69	T	21.17	1901	19.75
1901–02	T	T	0.78	0.64	3.48	0.90	1.23	7.27	2.65	0.98	1.05	T	18.98	1902	19.18
1902–03	T	T	T	1.70	1.98	2.32	8.73	1.76	6.23	0.56	T	T	18.28	1903	18.33
1903–04	0	T	T	0.17	4.25	1.63	1.05	5.89	6.01	1.29	0.30	T	20.59	1904	24.72
1904–05	0.02	0.06	5.07	2.37	1.07	1.59	4.04	2.70	3.15	1.33	2.05	0	23.45	1905	16.24
1905–06	0	T	T	T	0.92	2.05	3.90	4.30	5.02	0.92	2.75	0.56	20.42	1906	26.34
1906–07	0.08	0.11	0.18	0.03	1.59	6.90	4.41	3.02	8.24	0.11	0.04	1.28	26.17	1907	22.47
1907–08	T	0.02	0.11	1.36	0.04	3.66	4.88	5.39	0.90	0.22	0.76	0.01	17.35	1908	16.42
1908–09	0.02	0.01	0.13	0.61	1.34	2.15	10.51	7.53	3.27	T	T	T	25.57	1909	31.36
1909–10	0	T	0.80	1.23	2.43	5.59	3.24	2.09	3.78	0.31	2.03	0.02	19.52	1910	12.38
1910–11	T	0	0.05	0.65	0.48	1.73	13.79	3.02	4.57	0.89	0.28	0.03	25.49	1911	26.00
1911–12	T	0	T	0.28	0.60	2.54	2.47	0.41	4.10	1.38	1.47	0.81	14.06	1912	15.62
1912–13	T	0	1.25	0.49	1.94	1.30	3.84	0.43	1.47	......	......	......	....	1913	....
Averages	0.02	0.02	0.32	1.00	2.55	4.51	4.89	3.50	3.34	1.64	0.73	0.16	22.80	....	22.60

there were 23 rainy days. In January [illegible] there were [illegible] rainy days, but the total rainfall amounted to only [illegible] millimeters, 4.41 inches, which is less than a normal rainfall notwithstanding that the number of rainy days was nearly double the normal.

The rainiest February was in [illegible], when [illegible] millimeters, 12.52 inches, fell on [illegible] days. In February, [illegible] [illegible] millimeters, 9.24 inches, fell and there were [illegible] rainy days. In February, 1891, 234.7 millimeters, [illegible] inches, fell and there were 19 rainy days; in February, [illegible] [illegible] millimeters, [illegible] inches, fell, and there were [illegible] rainy days; in February, [illegible] [illegible] millimeters, 7.53 inches, fell and there were [illegible] rainy days.

Fig. 12

Annual frequency of rainy days, San Francisco

Cut from U. S. Wea. Bureau Bull. 44, Washington, 1913

The rainiest March was in 1879, when 222.2 millimeters, 8.75 inches, fell, and there were 14 rainy days; in 1907 the rainfall amounted to 213.9 millimeters, 8.42 inches, and there were 20 rainy days; in 1904 the rainfall amounted to 152.7 millimeters, 6.01 inches, and there were 23 rainy days; in 1884 209.3 millimeters, 8.24 inches, fell, and there were 16 rainy days.

The rainiest April was in 1880, when 205.5 millimeters, 10.06 inches, fell, and there were 17 rainy days. The average number of rainy days in April is 6, and the average rainfall 1.64 inches.

From May until October, inclusive, there is little rain.

The rainiest November was in 1885, when 299.2 millimeters, 11.78 inches, fell, and there were 19 rainy days. The average number of rainy days in November is 7.

The rainiest December was in 1866, when 385.1 millimeters, 15.16 inches, fell, and there were 18 rainy days; in December, 1889, 350.8 millimeters, 13.81 inches, fell, and there were 24 rainy days; in December, 1880, 12.33 inches fell, and there were 19 rainy days.

Number of Rainy Days in the Year.—In the past 62 years, 1850 to 1911, there have been 4207 rainy days. The yearly distribution is: January, 11; February, 10; March, 11; April, 6; May, 4; June, 1; July, 0; August, 0; September, 2; October, 4; November, 7; December, 11. For the year, average number 67.

Monthly Rainfall

January

From records covering a period of 63 years, 1850 to 1912, the mean January rainfall is 124.5 millimeters, 4.90 inches. The greatest rainfall was in 1862, when 24.36 inches fell, and the least was in 1852, when 14.7 millimeters, 0.58 of an inch, fell. There were 5 years in which the rainfall exceeded 250 millimeters, 10 inches, and 3 years in which the rainfall did not exceed 25 millimeters, 1 inch. The largest number of rainy days, 23, occurred in 1890, and the smallest number in 1852, when there were 4 rainy days. The average number of rainy days is 11. There have been 16 Januarys when the number of rainy days equaled or exceeded 15. In January, 1859, there were 26 consecutive days of fair weather.

February

The mean rainfall is 90.2 millimeters, 3.55 inches. Reduced to a 30-day normal, best obtained by eliminating the rainfall of leap years and adding twice the rainfall on the 14th, we have 96.8 millimeters, 3.81 inches. The average number of rainy days is 10. The heaviest February rainfall was 318.0 millimeters, 12.52 inches, in 1878, and the least, no rain, in 1864. Rainfalls

exceeding 250 millimeters, 10 inches, occurred once, in 1878, and rainfalls of less than 25 millimeters, 1 inch, occurred 13 times. The largest number of rainy days in any February was 19, which occurred in 1878, 1891, and 1902. There have been 11 Februarys when the number of rainy days did not exceed 5. The largest number of consecutive rainy days was 15, which occurred in 1891. The largest number of consecutive fair days was in February, 1864, when there were 29.

March

The mean rainfall is 85.3 millimeters, 3.36 inches. The greatest amount was in 1879, when 8.75 inches fell. The next rainiest March was in 1907, when 8.42 inches fell. The least was in 1898, when only 6.1 millimeters, 0.24 of an inch, fell. There have been 12 years in which the rainfall for March equaled or exceeded 125 millimeters, 5 inches, and 8 in which the total monthly amount did not exceed 25 millimeters, 1 inch. In 1908 there were 18 consecutive days without rain, and in 1911 21 days, with the exception of a trace on one day. In 1900 there were 23 consecutive days during which only a trace of rain fell. In 1875 there were 17 consecutive fair days, and in 1877 21 consecutive fair days. In 1861 the month was without rain until the 23rd. The average number of rainy days is 10. The largest number of rainy days in any month was in 1904, when there were 23, of which 19 were consecutive. The smallest number of rainy days was in 1901, when there were only 3. The heaviest 24-hour rainfall occurred on March 5, 1879, when 84.1 millimeters, 3.31 inches, fell.

April

The mean rainfall is 41.7 millimeters, 1.64 inches. The month of heaviest rainfall was in 1880, when 255.5 millimeters, 10.06 inches, were measured. There have been 6 Aprils out of the past 63 in which the rainfall equaled or exceeded 125 millimeters, 5 inches. There have been 27 in which the amount of rain did not exceed 25 millimeters, 1 inch. No rain fell in April, 1857, and there was only a trace of rain during April, 1909. The largest number of consecutive rainy days occurred in 1880, when it

rained for 11 days. The average number of rainy days in April is 6. The greatest 24-hour rainfall was 617 millimeters, 2.43 inches, on April 24, 1896.

May

The mean rainfall for May is 18.5 millimeters, 0.73 of an inch. The rainiest May was in 1883, when 89.4 millimeters, 3.52 inches, fell. There have been 5 Mays during the past 63 years when practically no rain fell. During 18 years the rainfall for May exceeded 25 millimeters, 1 inch. The average number of rainy days is 4. The greatest number of consecutive rainy days was 5, which occurred in 1860, 1889, and 1906. The largest number of rainy days in May was 11, in 1860 and 1883. The greatest 24-hour rainfall, 32.8 millimeters, 1.29 inches, occurred on May 5, 1889.

June

The mean rainfall for June for a period of 62 years is 4.1 millimeters, 0.16 of an inch. The month is practically rainless, only 3 times has the rainfall exceeded 25 millimeters, 1 inch. The heaviest June rainfall occurred in 1884, when 65.3 millimeters, 2.57 inches, fell. The average number of rainy days is 2. In 1888 there were 9 rainy days. The heaviest 24-hour rainfall occurred on June 12, 1884, when 31.2 millimeters, 1.23 inches, fell. Of the past 62 years 20 have been without rain during the month of June and 27 have had a rainfall not exceeding 0.2 millimeter, 0.01 of an inch.

July

The mean rainfall for July is 0.5 millimeter, 0.02 of an inch. In the past 62 years there have been only 3 showers in which the total amount exceeded 1.2 millimeters, 0.05 of an inch. Most of the rainfalls did not exceed 0.2 millimeter, 0.01 of an inch. The greatest 24-hour rainfall was 5.8 millimeter, 0.23 of an inch, on July 16, 1886.

August

August, like July, is practically a rainless month. The mean rainfall is 0.5 millimeter, 0.02 of an inch. There has never been an August when the total rainfall exceeded 6.4 millimeters, 0.25

of an inch. Only 14 of the 62 months under consideration have had a rainfall exceeding 0.2 millimeter, 0.01 of an inch. The greatest 24-hour rainfall was 3.0 millimeters, 0.12 of an inch, on August 26, 1858.

September

The mean rainfall is 7.6 millimeters, 0.30 of an inch. This, however, is larger than might be expected and is caused by phenomenal rainfall in September, 1904. In the 5 days, 22nd to 26th, more than 125 millimeters, 5 inches, of rain fell. The average number of rainy days is 2. The greatest number of consecutive rainy days is 5. There have been 19 Septembers without rain. Only once has the rainfall exceeded 125 millimeters, 5 inches, and only 4 times has it exceeded 25 millimeters, 1 inch. The greatest 24-hour rainfall, 78.5 millimeters, 3.09 inches, occurred on September 23, 1904.

October

The mean rainfall is 25.9 millimeters, 1.02 inches. The heaviest rainfall was in 1889, when 184.9 millimeters, 7.28 inches, fell. Other rainy Octobers were 1899, 95.6 millimeters, 3.92 inches; 1876, 85.6 millimeters, 3.36 inches; and 1849, 79.8 millimeters, 3.14 inches. There have been 9 Octobers without rain. The average number of rainy days is 4, and the greatest number, 13, occurred in 1889. The heaviest 24-hour rainfall, 52.3 millimeters, 2.06 inches, occurred on October 21, 1858.

November

The mean rainfall is 64.8 millimeters, 2.55 inches. The heaviest rainfall was in 1885, when 299.2 millimeters, 11.78 inches, fell. Other rainy Novembers were 1849, when 220.0 millimeters, 8.66 inches, fell; 1859, when 184.9 millimeters, 7.28 inches, fell. November, 1890, was without rain. The rainfall for November was less than 25 millimeters, 1 inch, in 21 years. The average number of rainy days is 7. The greatest number of rainy days was 19, in 1885. The greatest 24-hour rainfall, 101.1 millimeters, 3.98 inches, fell on November 26, 1864, and again on November 23, 1874.

December

The mean rainfall is 115.8 millimeters, 4.56 inches. The heaviest rainfall was in 1866, when 15.16 inches fell. Other rainy Decembers were 1852, 335.8 millimeters, 13.20 inches; 1871, 364.7 millimeters, 14.36 inches; 1880, 313.2 millimeters, 12.33 inches; 1889, 350.8 millimeters, 13.81 inches; and 1894, 9.01 inches. December, 1876, was rainless. Less than 25 millimeters, 1 inch, of rain fell in 1854, 1865, 1874, 1878, 1883, and 1901. The average number of rainy days is 11. The greatest number, 24, was in 1889. The greatest 24-hour rainfall, 108.7 millimeters, 4.28 inches, fell on the 19th, 1866.

In connection with the absence of rain during December, 1876, it may be noted that there was no rain between November 16, 1876, and January 16, 1877. Or, in other words, there was a period of 60 consecutive days without rain in midwinter.

THUNDERSTORMS

Few thunderstorms occur at San Francisco. In the past twenty years there have been 28, but not a single one that could be considered as severe. The following table shows the distribution:

January 2	April 3	July 1	October 3
February 3	May 1	August 2	November 3
March 1	June 1	September 2	December 6

The greatest number recorded in any one year was 8, in 1906. During the past twenty years there have been eight years without record of a thunderstorm. The storms are mild in character, the lightning flashes of moderate intensity, and the thunder usually limited to a few peals. Damage from lightning is practically unknown, although some flagpoles have been shattered and one or two trees struck in the past sixty years.

HAIL

There have been 56 hailstorms in the past 20 years. January and December are the months of maximum frequency. There is no record of any hailstorm occurring during June, July, August, and September.

Snowstorms

Snow is of rare occurrence. During winter storms the tops of the hills in the southwestern portion of the city are occasionally whitened by snowflakes. These melt rapidly and snow of appreciable depth is rare. However, snow can be seen frequently during winter months on Mount Tamalpais, Mount Diablo, and the peaks of the Mount Hamilton Range. The heaviest snowfall in the bay section occurred January 9, 1913, when Mount Tamalpais and Angel Island were covered.

Dates of Snowfall at San Francisco Since March 1, 1871

January 21, 1876—Light snow fell for ten minutes.

December 31, 1882—Heavy snow fell from 11:30 A.M. to 4:20 P.M., amount 89 millimeters, 3.5 inches.

February 6, 1883—A few flakes of snow fell during the day.

February 7, 1884—Snow fell at intervals during the day, depth varying from 25 to 50 millimeters, 1 to 2 inches.

February 5, 1887—Snow fell during the day; depth at office 94 millimeters, 3.7 inches, while in the western portion of the city it was fully 175 millimeters, 7 inches, deep.

January 4, 1888—A few flakes of snow fell during the day.

January 16, 1888—Light snow fell to the depth of 0.2 millimeter, 0.1 inch.

March 2, 1894—A few flakes of snow fell during the day.

March 2, 1896—Snow mixed with rain fell at intervals during the day.

March 3, 1896—Heavy snow fell during the night; depth at office at 8 A.M., 1.3 millimeters, 0.5 inch.

February 3, 1903—Snow, large flakes, 11:16 to 11.20 A.M.

March 5–6, 1908—Trace of snow fell.

February 26 and 27, 1911—1.0 millimeter, 0.04 of an inch, of snow fell.

January 9, 1913—Light snow fell, which melted quickly.

GREATEST PRECIPITATION AT SAN FRANCISCO IN INCHES AND HUNDREDTHS IN 24 HOURS FOR EACH MONTH

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct	Nov.	Dec.	Greatest monthly
1871	......	......	0.57	1.28	0.13	0.01	0.00	0.02	0.00	0.07	1.24	3.14	3.14
1872	2.36	1.28	0.73	0.35	0.15	0.03	0.01	0.00	0.04	0.11	2.06	2.33	2.36
1873	1.02	0.82	0.54	0.36	0.00	0.01	0.01	0.05	0.00	0.77	0.80	2.33	2.33
1874	1.61	0.81	0.65	0.70	0.23	0.13	0.00	0.00	0.02	1.58	3.98	0.15	3.98
1875	2.19	0.27	0.45	0.06	0.14	0.90	0.00	0.00	0.00	0.22	2.37	1.50	2.37
1876	1.76	1.80	1.59	0.60	0.24	0.04	0.01	0.01	0.20	1.39	0.19	0.00	1.80
1877	1.63	0.52	0.56	0.08	0.18	0.01	0.02	0.00	0.00	0.36	0.56	1.11	1.63
1878	1.98	1.92	1.01	0.61	0.14	0.01	0.01	T	0.45	1.27	0.45	0.33	1.98
1879	1.04	1.66	3.31	0.72	0.93	0.05	0.01	0.02	T	0.56	1.38	1.55	3.31
1880	1.03	0.64	0.57	2.21	0.84	0.00	0.00	0.00	0.00	0.05	0.32	2.36	2.36
1881	4.67	1.37	0.69	1.09	0.17	0.41	0.00	0.00	0.25	0.21	1.34	1.35	4.67
1882	0.57	0.82	0.86	0.44	0.15	0.02	0.00	0.00	0.26	1.40	2.41	0.76	2.41
1883	1.30	0.71	1.63	0.76	1.23	0.01	0.00	0.00	0.42	1.19	1.01	0.28	1.63
1884	1.44	1.62	2.21	1.66	0.12	1.23	0.00	0.03	0.21	1.15	0.19	2.07	2.21
1885	0.97	0.15	0.55	2.03	0.04	0.10	0.05	T	0.11	0.70	2.58	2.78	2.78
1886	2.40	0.18	0.65	1.36	0.21	0.01	0.23	0.00	0.01	0.72	0.77	1.10	2.40
1887	0.80	3.60	0.52	1.45	0.03	0.07	T	0.01	0.18	0.00	0.48	1.14	3.60
1888	1.58	0.38	1.34	0.11	0.19	0.10	0.01	0.01	0.92	0.05	1.68	1.51	1.68
1889	0.81	0.59	3.08	0.30	1.29	0.03	0.01	T	T	2.03	0.92	1.46	3.08
1890	2.08	1.63	1.86	0.55	0.53	0.05	0.02	0.00	0.31	0.00	0.00	1.90	2.08

GREATEST PRECIPITATION AT SAN FRANCISCO IN INCHES AND HUNDREDTHS IN 24 HOURS FOR EACH MONTH—*Continued*

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Greatest monthly
1891	0.75	3.38	0.68	1.20	0.61	0.10	0.09	0.02	0.63	0.03	0.26	2.21	3.38
1892	1.06	1.03	0.90	0.38	1.15	T	0.00	0.00	0.02	0.91	1.46	2.34	2.34
1893	1.39	1.06	0.98	0.71	0.14	0.03	0.02	0.00	0.12	0.10	1.69	0.97	1.69
1894	2.61	1.05	0.34	0.30	0.68	0.22	T	0.00	1.04	0.64	0.88	1.64	2.61
1895	1.96	1.44	0.67	0.89	0.27	0.00	0.01	0.00	0.62	0.06	1.06	0.51	1.96
1896	1.85	0.18	0.84	2.43	0.34	0.00	0.04	0.06	0.41	1.46	2.79	1.65	2.79
1897	1.08	1.23	1.42	0.20	0.61	0.19	T	T	0.08	1.41	0.42	1.02	1.42
1898	0.33	0.78	0.13	0.19	1.23	0.18	0.00	T	0.73	0.45	0.36	0.70	1.23
1899	0.98	0.08	2.15	0.45	0.77	0.01	0.00	T	0.00	1.94	1.51	1.17	2.15
1900	1.92	0.50	0.90	0.36	0.22	0.04	T	T	0.45	0.34	1.66	0.74	1.92
1901	1.75	1.95	0.67	0.88	0.46	T	T	T	0.67	0.43	1.20	0.01	1.95
1902	0.35	1.08	0.69	0.23	0.56	0.00	T	T	T	0.69	0.77	0.85	1.08
1903	1.00	0.63	1.30	0.39	T	T	0.00	T	T	0.15	2.39	1.06	2.39
1904	0.59	2.73	1.32	0.40	0.30	T	0.02	0.05	3.58	0.72	0.56	0.57	3.58
1905	1.08	1.23	0.93	0.49	1.18	0.00	0.00	T	T	T	0.38	0.65	1.23
1906	1.06	1.32	1.37	0.51	1.42	0.23	0.05	0.08	0.12	0.01	0.67	2.57	2.47
1907	0.91	1.52	1.82	0.08	0.02	0.74	T	0.02	0.11	0.99	0.02	0.96	1.82
1908	2.10	2.04	1.41	0.10	0.24	0.01	0.02	0.01	0.10	0.44	0.70	0.99	2.10
1909	1.61	1.87	1.16	T	T	T	T	0.00	0.67	0.82	0.97	1.41	1.87
1910	0.83	0.64	1.17	0.23	0.02	0.02	T	0.00	0.04	0.48	0.27	0.99	1.17
1911	2.48	0.68	1.98	0.81	0.15	0.03	T	0.00	T	0.16	0.45	0.66	2.48
1912	1.05	0.19	2.09	0.80	0.74	0.68	T	0.00	1.21	0.26	0.94	0.59	2.09
Year	4.67	3.60	3.31	2.43	1.42	1.23	0.23	0.08	3.58	2.03	3.98	3.14	4.67

Dates When the Precipitation Equalled or Exceeded 65 Millimeters, 2.50 Inches, in Any Consecutive 24 Hours

			Amount	
Year	Month	Dates	Mm.	Inches
1871	December	17–18	71.9	2.83
1871	December	18–19	79.8	3.14
1874	November	22–23	101.1	3.98
1879	March	4– 5	84.1	3.31
1881	January	28–29	118.6	4.67
1885	November	23–24	65.5	2.58
1885	December	21	70.6	2.78
1887	February	4– 5	91.4	3.60
1889	March	12–13	78.2	3.08
1891	February	14–15	85.8	3.38
1894	January	19–20	66.3	2.61
1896	November	23–24	70.9	2.79
1904	February	11–12	69.3	2.73
1904	September	23	90.9	3.58

Maximum Rates of Rainfall

			Amount		
Year	Month	Day	Mm.	Inches	
1901	February	22	4.3	0.17	5 minutes
1901	February	22	5.3	0.21	10 minutes
1902	October	23	3.8	0.16	5 minutes
1902	October	23	5.1	0.20	10 minutes
1903	February	7	4.8	0.19	5 minutes
1903	February	7	5.8	0.23	10 minutes
1904	September	23	3.8	0.16	5 minutes
1904	September	23	8.2	0.32	10 minutes
1904	September	23	10.9	0.43	15 minutes
1904	September	23	18.8	0.74	30 minutes
1904	September	23	24.6	0.97	1 hour
1904	September	23	32.8	1.29	2 hours
1904	September	23	90.9	3.58	16¼ hours
1912	March	5	2.5	0.10	5 minutes
1912	March	5	7.1	0.28	10 minutes
1912	March	5	13.5	0.53	15 minutes
1912	March	5	18.3	0.72	20 minutes
1912	March	5	19.6	0.77	25 minutes
1912	March	5	19.8	0.78	30 minutes

Mr. John Pettee states that on December 20–21, 1866, he measured the rainfall in San Francisco as follows:

Time	Date	Mm.	Inches	Mm. per hour	Inches per hour
11:30 a.m. to 4:45 p.m.	Dec. 20	50.0	1.97	9.4	0.37
4:45 p.m. to 7:45 p.m.	Dec. 20	57.7	2.27	19.3	.76
7:45 p.m. to 9:50 p.m.	Dec. 20	21.6	.85	10.4	.41
9:50 p.m. to 1:00 a.m.	Dec. 20-21	30.5	1.20	9.9	.39
1:00 a.m. to 8:15 a.m.	Dec. 21	37.3	1.47	5.1	.20
Total		197.1	7.76	9.4	.37

The reason for many measurements was that the gauge held only about 65 millimeters, 2.50 inches.

SACRAMENTO RAINFALL, MONTHLY, SEASONAL, AND ANNUAL, 1849–1912

Seasons	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Annual
1849–50	......	......	0.25	1.50	2.25	12.50	4.50	0.50	10.00	4.25	0.25	......	36.00	19.50
1850–51	......	......	......	......	T	T	0.65	0.35	1.88	1.14	0.69	......	4.71	15.10
1851–52	......	......	1.00	0.18	2.14	7.07	0.58	0.12	6.40	0.19	0.30	......	17.98	26.99
1852–53	T	......	T	......	6.00	13.40	3.00	2.00	7.00	3.50	1.45	T	36.35	19.99
1853–54	......	......	T	T	1.50	1.54	3.25	8.50	3.25	1.50	0.21	0.31	20.06	19.83
1854–55	......	T	T	1.01	0.65	1.15	2.67	3.46	4.20	4.32	1.15	0.01	18.62	18.56
1855–56	......	......	T	......	0.75	2.00	4.92	0.69	1.40	2.13	1.84	0.03	13.76	14.26
1856–57	......	......	T	0.20	0.65	2.40	1.38	4.80	0.68	T	T	0.35	10.46	12.91
1857–58	......	T	......	0.66	2.41	2.63	2.44	2.46	2.88	1.21	0.20	0.10	14.99	16.80
1858–59	0.01	T	T	3.01	0.15	4.34	0.96	3.91	1.64	0.98	1.04	......	16.04	16.86
1859–60	......	......	0.02	......	6.48	1.83	2.31	0.93	5.11	2.87	2.49	0.02	22.06	19.79
1860–61	0.63	......	0.06	0.91	0.18	4.28	2.67	2.92	3.32	0.48	0.59	0.14	16.18	21.48
1861–62	0.55	......	......	T	2.17	8.64	15.04	4.26	2.80	0.82	1.81	0.01	36.10	27.44
1862–63	......	0.01	......	0.36	T	2.33	1.73	2.75	2.36	1.69	0.36	0	11.59	12.20
1863–64	......	......	T	......	1.49	1.82	1.08	0.19	1.30	1.08	0.74	0.09	7.79	19.27
1864–65	......	0.08	T	0.12	6.72	7.87	4.78	0.71	0.48	1.37	0.46	......	22.59	11.15
1865–66	T	......	0.08	0.48	2.43	0.36	7.70	2.01	2.02	0.48	2.25	0.10	17.91	26.52
1866–67	0.02	......	......	T	2.43	9.51	3.44	7.10	1.01	1.80	0.01	......	25.32	30.03
1867–68	......	......	0.01	......	3.81	12.85	6.04	3.15	4.35	2.31	0.27	T	32.79	19.50
1868–69	......	......	......	......	0.77	2.61	4.79	3.63	2.94	1.24	0.65	0.01	16.64	18.19
1869–70	......	......	T	2.12	0.85	1.96	1.37	3.24	1.64	2.12	0.27	T	13.57	10.21
1870–71	T	T	......	0.02	0.58	0.97	2.08	1.92	0.69	1.45	0.76	T	8.47	18.92
1871–72	......	......	T	0.21	1.22	10.59	4.04	4.74	1.94	0.61	0.28	0.02	23.65	19.17

SACRAMENTO RAINFALL, MONTHLY, SEASONAL, AND ANNUAL, 1849–1912—*Continued*

Seasons	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Annual
1872–73	......	......	T	0.22	1.93	5.39	1.23	4.36	0.55	0.51	......	T	14.19	18.20
1873–74	0.02	T	......	0.31	1.21	10.01	5.20	1.86	3.05	0.99	0.37	T	22.92	17.92
1874–75	T	......	0.05	2.26	3.80	0.44	8.70	0.55	0.80	T	T	1.10	17.70	23.31
1875–76	......	......	......	0.44	6.20	5.52	4.99	3.75	4.15	1.10	0.15	......	26.30	18.12
1876–77	0.21	0.02	T	3.45	0.30	......	2.77	1.04	0.56	0.19	0.64	0.01	9.19	8.44
1877–78	T	T	......	0.73	1.07	1.43	9.26	8.04	3.09	1.07	0.17	......	24.86	23.45
1878–79	......	......	0.29	0.55	0.51	0.47	3.18	3.88	4.88	2.66	1.30	0.13	17.85	22.37
1879–80	T	T	......	0.88	2.05	3.41	1.61	1.83	1.70	14.20	0.76	......	26.47	31.99
1880–81	T	......	......	......	0.05	11.81	6.14	5.06	1.37	1.64	T	0.50	26.57	20.71
1881–82	T	......	0.30	0.55	1.88	3.27	1.89	2.40	3.78	1.99	0.35	0.10	16.51	18.06
1882–83	T	......	0.57	2.63	3.22	1.13	2.23	1.11	3.70	0.67	2.85	......	18.11	13.48
1883–84	......	......	0.90	0.97	0.61	0.44	3.43	4.46	8.14	4.32	0.06	1.45	24.78	34.92
1884–85	......	T	0.60	2.01	......	10.45	2.16	0.49	0.08	0.68	T	0.11	16.58	20.72
1885–86	T	......	0.08	0.02	11.34	5.76	7.95	0.29	2.68	4.08	0.07	......	32.27	18.17
1886–87	......	......	......	0.68	0.21	2.21	1.12	6.28	0.94	2.53	T	......	13.97	13.43
1887–88	......	T	0.02	......	0.45	2.09	4.81	0.57	3.04	0.10	0.40	0.08	11.56	18.46
1888–89	T	T	0.55	......	4.28	4.63	0.15	0.33	6.25	0.26	3.25	0.25	19.95	27.48
1889–90	......	......	......	6.02	3.15	7.82	6.62	4.06	3.00	1.33	1.80	......	33.80	20.95
1890–91	......	T	0.80	T	......	3.34	0.53	6.61	1.78	2.04	0.66	0.05	15.81	15.63
1891–92	T	......	0.10	0.10	0.48	3.28	1.78	2.84	3.02	1.20	2.38	T	15.18	23.60
1892–93	......	......	0.18	0.70	6.60	4.90	3.27	2.66	3.51	1.08	1.05	......	23.95	16.59
1893–94	T	T	0.22	0.12	2.92	1.76	4.17	3.92	0.74	0.34	1.70	0.46	16.35	22.61

SACRAMENTO RAINFALL, MONTHLY, SEASONAL, AND ANNUAL, 1849-1912—*Concluded*

Seasons	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Annual
1894–95	T	T	0.88	1.06	0.48	8.86	8.42	1.84	1.20	0.86	0.51	......	24.11	17.38
1895–96	0.04	T	1.26	0.17	1.54	1.54	9.76	0.09	2.57	5.34	0.92	......	23.23	25.06
1896–97	T	0.20	0.31	0.55	3.56	1.76	3.66	4.15	2.54	0.25	0.30	0.04	17.32	15.32
1897–98	......	0.01	0.16	1.96	0.61	1.64	0.98	3.19	0.04	0.28	1.50	0.14	10.51	10.04
1898–99	......	......	0.36	0.64	0.61	2.30	3.94	0.04	6.02	0.10	0.54	0.49	15.04	21.14
1899–1900	0	0.02	0	4.46	2.62	2.91	3.54	0.32	1.61	1.88	2.88	T	20.24	17.91
1900–01	T	0	0.06	1.74	4.50	1.38	3.70	5.32	0.48	2.23	0.80	T	20.21	18.52
1901–02	0	T	0.56	1.56	2.68	1.19	0.95	6.52	1.99	1.36	0.45	0.01	17.27	17.88
1902–03	0	T	0	1.67	2.02	2.91	3.05	1.70	4.81	0.46	T	T	16.62	14.70
1903–04	0	0	0	0.12	3.44	1.12	0.45	5.26	5.43	1.02	0.03	T	16.87	20.99
1904–05	T	0.07	3.62	1.86	2.05	1.20	3.33	2.47	3.75	1.18	2.45	0	21.98	14.97
1905–06	0	T	0.03	0	1.20	0.56	6.63	3.02	8.45	1.21	2.24	0.59	23.93	30.70
1906–07	0	T	0.20	T	0.99	7.37	4.63	2.37	7.28	0.25	0.10	0.85	24.04	20.05
1907–08	0	0	T	1.20	0.04	3.33	3.84	2.75	0.42	0.08	0.54	T	12.20	11.21
1908–09	T	0	0.05	0.26	1.23	2.04	9.65	6.68	1.84	T	T	0.03	21.78	24.87
1909–10	0	0	0.21	1.27	1.32	3.87	1.48	0.83	3.06	0.11	0.03	T	12.18	7.78
1910–11	T	0	0.20	0.28	0.17	1.62	12.72	1.88	4.30	0.66	0.03	0.12	21.98	21.11
1911–12	0	0	T	0.18	0.15	1.07	2.74	0.23	1.97	1.69	0.94	0.58	9.55	11.01
1912–13	T	0	1.25	0.58	0.80	0.23	......	......	......	......	......	......	....	....
Averages 62 yrs.	0.02	0.01	0.24	0.83	2.00	3.90	3.94	2.85	2.98	1.58	0.80	0.13	19.32	19.11

SACRAMENTO PRECIPITATION DATA, MEAN FOR 36 YEARS

Month	Mean	Absolute maximum	Absolute minimum
December	3.90	11.81	0.23
January	3.94	12.72	0.15
February	2.85	8.09	0.04
Winter mean	10.69	......	......
March	2.98	8.45	0.04
April	1.69	14.20	T
May	0.80	3.25	T
Spring mean	5.47	......	......
June	0.13	1.45	0
July	0.02	0.04	0
August	0.01	0.20	0
Summer mean	0.16	......	......
September	0.24	3.62	0
October	0.83	6.02	0
November	2.00	11.34	0
Fall mean	3.07	......	......
Annual mean	19.39	......	......

RECORDS OF PRECIPITATION IN CALIFORNIA

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Aguanga	1,986	....	Sept., 1908	15.42	12.83	4.76
Alameda	19	....	Feb., 1909–Feb., 1912	....	....	12.50
Alturas	4,460	....	April, 1904	....	....	4.47
Anaheim	134	11.56	Jan., 1878	26.17	4.42	10.58
Anderson	550	....	April, 1909–April, 1910	....	....	6.95
Angels Camp	1,535	....	Jan., 1908	50.36	23.47	26.24
Angiola	208	6.65	July, 1899	8.89	3.15	3.76
Antelope Valley	1,205	....	Sept., 1911	....	....	....
Antioch	46	12.93	Jan., 1879	24.57	5.30	11.33
Aptos	102	27.36	Jan., 1885	49.07	11.51	20.33
Arrowhead Springs	2,000	....	April, 1909	....	....	8.86
Auburn	1,360	35.13	Jan., 1871	56.73	18.86	23.08
Avalon	30	....	Nov., 1909	....	....	6.24
Azusa	540	17.86	Sept., 1897	28.24	7.11	11.70
Bagdad	784	3.08	Jan., 1903	10.20	T	3.20
Bakersfield	394	5.92	Jan., 1889	8.72	2.77	2.53
Barstow	2,105	3.62	Jan., 1889	7.03	0.57	3.87[1]
Bear River	5,800	....	Aug., 1907	74.86	33.83	34.68
Bear Valley	4,400	21.26	Jan., 1900	30.32	10.21	9.29
Bear Valley Dam	6,500	32.65	Jan., 1892	50.29	11.29	26.14[2]
Beaumont	2,558	....	Jan., 1911	....	....	....

[1] 1892 and 1898 to 1902 missing.
[2] 1908 and January to August, 1909, missing.

Records of Precipitation in California—*Continued*

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Beaumont (near)	3,045	....	Jan., 1911	....	....	....
Beckwith	5,005	....	Feb., 1908–Dec., 1909	....	....	16.51
Belotta	....	....	Jan., 1911	....	....	13.91
Ben Lomond	300	57.22	Feb., 1899	78.49	34.84	42.57
Berkeley	320	26.62	Jan., 1887	46.00	14.40	15.99
Biggs	98	22.24	Jan., 1899	29.06	12.29	12.97
Bishop	4,450	5.54	Jan., 1895	10.97	1.69	6.58
Bishop Creek	8,500	....	May, 1910	....	....	11.35
Blocksburg	1,700	....	June, 1905	....	....	34.78
Blue Cañon	4,695	74.23	Jan., 1899	100.47	40.33	48.35
Blythe	268	....	Feb., 1909	....	....	1.98
Boca	5,531	20.29	Jan., 1870	52.15	7.60	20.59
Bodie	8,248	14.49	March, 1895–Jan., 1907	23.62	9.12	7.39
Boulder Creek	470	58.01	Sept., 1888	123.65	24.25	39.42
Bowmans Dam	5,500	75.90	Sept., 1871	142.07	29.40	47.53[3]
Branscomb	2,000	91.94	Jan., 1900	132.62	66.86	55.79
Brawley	—105	....	Jan., 1912	....	....	....
Burney	3,330	....	Jan., 1910	....	....	11.92
Butte Valley	4,020	54.93	Nov., 1903–March, 1912	71.32	33.18	34.51
Cabazon	1,779	11.60	Jan., 1898	18.36	5.79	9.09
Cahuilla	3,600	....	Jan., 1911	....	....	....
Calexico	0	....	Jan., 1905	4.79	1.95	3.76
Caliente	1,290	11.12	Feb., 1876	19.96	3.16	5.59
Calistoga	363	36.97	Jan., 1893	67.51	20.52	29.23
Campbell	217	15.21	Jan., 1897	23.38	8.20	12.61
Campo	25.43	20.15	March, 1877	32.51	8.79	16.10[4]
Camptonville	3,500	....	Feb., 1907	....	....	55.43
Cedarville	4,675	14.44	June, 1894	18.62	9.18	7.28
Chester	4,550	....	June, 1910	....	....	17.35
Chico	189	23.39	Jan., 1871	37.39	12.97	14.38
Chico (near)	....	....	Sept., 1904	....	....	16.62
China Flat	600	....	July, 1909	....	....	13.24
Chino	714	15.42	Jan., 1893	26.36	6.28	9.69
Cisco	5,939	52.01	Feb., 1870	97.63	31.90	33.46
Claremont	1,200	17.07	May, 1891	26.29	7.85	9.51
Cloverdale	340	44.83	April, 1902	64.86	24.85	34.20
Coalinga	663	....	Aug., 1911	....	....	....
Colfax	2,421	48.91	Feb., 1870	89.80	27.61	29.94
Colgate	700	....	Jan., 1907	....	....	29.10
Colusa	60	16.29	Feb., 1871	33.01	7.18	13.07[5]
Corning	277	21.86	Jan., 1886	34.64	9.11	14.62
Corona	615	....	July, 1908	....	....	7.38
Craftonville	1,759	14.21	May,1892	23.00	5.93	7.52

[3] February, 1893, to August, 1894, May, 1910, to December, 1911, missing.
[4] September, 1894, to August, 1899, missing.
[5] 1891 and 1892, 1895 to 1902 missing.

RECORDS OF PRECIPITATION IN CALIFORNIA—*Continued*

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Crescent City	50	73.27	Jan., 1891–Dec., 1908	113.06	53.83	29.84
Crockers	4,452	55.79	July, 1896–Dec., 1910	83.54	31.37	29.67
Cuyamaca	4,677	39.26	Sept., 1878	63.84	15.05	34.70
Davisville	51	17.23	Jan., 1872	37.41	5.12	13.08
Deer Creek	3,700	....	March, 1907	....	....	56.32
Dehesa	....	15.97	Oct., 1901–July, 1909	22.43	12.05	9.62
Delano	319	6.12	Jan., 1876	11.52	1.41	3.76
Del Monte	25	....	Jan., 1911	....	....	....
Delta	1,138	64.43	Jan., 1883	124.47	25.50	53.28
Denair	126	11.14	June, 1899	13.86	5.93	7.08
De Sabla	2,500	....	Jan., 1904	....	....	39.58
Descanso	3,400	22.11	Jan., 1896	27.54	11.94	13.84[6]
Devils Cañon	2,000	....	Jan., 1912	....	....	....
Dinuba	333	....	Jan., 1909	....	....	5.01
Dobbins	1,650	....	Jan., 1904	....	....	29.75
Downieville	3,150	....	Dec., 1892–Aug., 1906	39.94	16.35	13.45
Drytown	790	23.00	Sept., 1908	....	....	42.81
Dudley	595	....	Aug., 1911	....	....	....
Dudleys	3,000	....	May, 1908	....	....	29.48
Dunlap (near)	2,800	....	March, 1911	....	....	....
Dunnigan	65	20.14	Jan., 1877	37.45	11.61	15.13
Dunsmuir	2,285	58.04	Jan., 1889	119.02	25.74	32.60
Durham	160	25.78	Feb., 1895	32.46	16.31	13.47
Dyerville	250	....	Oct., 1907–Nov., 1911	....	....	32.53
East Park	....	....	Jan., 1911	....	....	....
Edgewood	2,955	19.70	Sept., 1888	36.34	7.67	12.21[7]
Edison	2,500	....	Jan., 1904	22.95	8.29	8.10
Edmonton	4,750	71.79	Jan., 1877–June, 1905	95.01	42.04	32.70[8]
Él Cajon	482	12.49	Feb., 1899	20.50	5.71	9.22
Electra	725	....	Jan., 1904	50.97	....	23.56
Elsinore	1,234	13.62	Jan., 1887–Oct., 1912	25.96	5.98	11.98
Emigrant Gap	5,230	52.37	March, 1870	94.30	17.35	33.87[9]
Escondido	657	14.56	Jan., 1894	25.43	8.15	11.98[10]
Eureka	64	46.24	Jan., 1887	74.10	32.74	19.49
Fairmont (near)	3,047	....	Feb., 1909	....	....	10.50
Fallbrook	700	17.27	Jan., 1876–Feb., 1904	40.77	7.70	15.53
Farmington	111	16.66	Jan., 1877	24.82	7.93	10.43
Felton	275	49.05	Aug., 1888	100.64	28.55	34.95[11]

[6] 1903 to 1908 missing.
[7] September, 1902, to December, 1905, missing.
[8] September, 1882, to October, 1892, missing.
[9] 1897 to 1899, 1901 to 1904 missing.
[10] 1896 and 1897 missing.
[11] 1901 and 1902 missing.

RECORDS OF PRECIPITATION IN CALIFORNIA—*Continued*

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Firebaugh	150	8.39	Jan., 1873	18.84	2.24	9.91[12]
Folsom	252	24.51	Jan., 1872	43.31	10.19	21.06
Fordyce Dam	6,500	74.01	Oct., 1894	116.52	40.08	55.33
Fort Bidwell	4,640	20.80	Jan., 1867	34.02	8.43	12.71[13]
Fort Bragg	74	39.58	June, 1895	56.88	24.34	27.02[14]
Fort Ross	100	54.21	Jan., 1875	92.86	26.69	37.44
Fouts Springs	1,650	....	Dec., 1903	....	....	30.36
Fresno	293	10.04	July, 1881	19.45	4.96	9.54
Friant	345	12.99	July, 1896	17.35	7.53	7.84[15]
Fruto	624	21.74	Jan., 1889–Dec., 1911	38.04	8.32	11.73
Galt	49	18.76	Jan., 1878	33.60	9.61	16.18
Georgetown	2,650	58.60	Jan., 1873	95.27	31.94	39.65
Gilroy	193	20.09	Jan., 1874	37.75	6.53	12.80
Gilta	3,300	....	April, 1910	....	....	....
Glendora	740	21.84	Jan., 1892–May, 1912	39.27	6.39	14.56[16]
Glen Ranch	3,256	28.90	Sept., 1899	49.69	15.00	22.52
Glennville	3,300	....	Sept., 1909	....	....	12.43
Glenwood	885	....	Feb., 1909	....	....	32.86[17]
Gold Run	3,222	55.29	Feb., 1899	77.55	28.06	27.60
Gonzales	127	12.89	Feb., 1899	22.29	8.05	8.09
Grass Valley	2,090	53.32	Dec., 1872	89.81	28.45	38.34[18]
Greenland Ranch	178	....	July, 1911	....	....	....
Greenville	3,600	44.73	March, 1894	67.34	23.30	32.71
Gridley	97	....	Aug., 1907	....	....	11.84
Groveland	1,400	....	Jan., 1904	59.75	....	30.76[19]
Guinda	350	22.62	Jan., 1896	28.88	15.71	13.27
Hanford	249	9.20	June, 1899	12.51	5.99	4.69
Head Dam	1,500	....	March, 1907	....	....	41.03
Healdsburg	52	43.54	Jan., 1877	72.37	16.35	33.68
Hearst	1,800	....	Jan., 1910	....	....	12.80
Heber	—20	....	Jan., 1906	....	....	2.08
Helen Mine	2,750	100.14	July, 1900	126.70	54.55	71.54
Hetch Hetchy	3,665	....	Oct., 1910	....	....	21.45
Holcomb	7,800	....	Sept., 1909	....	....	7.35
Hollister	284	13.12	Jan., 1874	23.80	4.69	8.11
Hornbrook	2,154	15.17	Jan., 1888	25.65	7.46	9.91
Hot Springs	3,300	....	Feb., 1907	38.59	....	16.06
Hullville	2,250	....	April 1907	62.53	....	34.47
Hyampom	....	....	July, 1912	....	....	....

[12] 1886 to 1907 missing.
[13] 1890 to 1912 missing.
[14] April, 1900, to December, 1901, missing.
[15] 1904 and 1905 missing.
[16] May to December, 1903, missing.
[17] 1901 to 1906 missing.
[18] August, 1907, to July, 1908, missing.
[19] July, 1907, to March, 1908, missing.

RECORDS OF PRECIPITATION IN CALIFORNIA—*Continued*

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Idyllwild	5,250	27.18	Feb., 1901–May, 1912	41.66	14.95	16.15
Imperial	—65	4.58?	Jan., 1902–Aug., 1908	11.02	.35	6.12
Independence	3,907	5.25	March, 1898	8.08	1.58	3.90
Indio	—20	2.68	Jan., 1878	6.01	.40	6.01
Inskip	4,975	....	March, 1907	....	....	64.58
Ione	287	21.15	Jan., 1878	33.82	11.35	17.19
Iowa Hill	2,825	53.63	Jan., 1879–May, 1910	91.04	29.47	28.90
Isabella	2,500	9.63	Feb., 1896–June, 1910	23.60	5.38	9.41[20]
Jackson (near)	1,900	35.82	Nov., 1891–Oct., 1903	50.10	19.53	15.50
Jacksonville	650	....	Jan., 1907	....	....	18.78
Jamestown	1,471	33.92	Jan., 1903	48.49	18.95	21.30
Jenny Lind	....	....	Jan., 1907	....	....	14.63
Jolon	960	18.30	Sept., 1882	36.91	5.33	13.15
Julian	4,500	26.30	Jan., 1891	61.52	10.75	17.00
Keeler	3,620	3.06	Jan., 1885–Dec., 1908	8.60	.53	3.30
Kennedy Mine	1,500	37.30	Jan., 1892	54.07	17.38	20.68
Kennett	730	....	Jan., 1907	....	....	54.08[21]
Kentfield	65	50.28	Jan., 1888	88.25	28.41	31.42
Kernville	2,600	9.58	Jan., 1894	21.22	3.66	8.52
King City	333	11.44	Jan., 1887	23.59	3.97	8.90
Knights Landing	45	18.52	Jan., 1878	33.29	9.85	12.52
Knob	2,860	....	Sept., 1908–Oct., 1909	....	....	19.31
Kono Tayee	1,325	23.00	Jan., 1874–Sept., 1904	38.98	12.08	14.45[22]
La Grange	293	16.76	Jan., 1868	30.34	5.74	12.00[23]
La Jolla	....	....	April, 1911	....	....	....
Lake Eleanor	4,700	....	Nov., 1909	....	....	26.56
Lakeside	450	....	Nov., 1908	....	....	5.47
Lake Spaulding	4,600	77.28	Sept., 1894	102.56	40.85	49.02
La Porte	5,000	85.88	April, 1894	119.07	48.12	63.52[24]
Laurel	910	52.81	Jan., 1889	69.92	24.84	38.00
Laytonville	1,600	....	Sept., 1904	....	....	46.55
Le Grand	255	13.01	June, 1899	20.07	4.87	7.17
Lemon Cove	600	16.71	March, 1899	27.58	11.04	9.82
Lick Observatory	4,209	32.28	Jan., 1881	58.09	17.66	18.18[25]
Livermore	485	15.55	Jan., 1871	28.66	6.01	12.60
Lodi	35	19.64	Jan., 1888–Nov., 1912	33.45	9.30	15.01
Lone Pine	3,661	....	Aug., 1904	6.82	3.41	2.92
Long Camp	4,100	....	Jan., 1909–Dec., 1910	....	....	29.44

[20] January to August, 1897, missing.
[21] June to October, 1907, and 1908 missing
[22] October, 1884, to September, 1892, missing.
[23] May, 1900, to October, 1908, missing.
[24] December, 1904, to September, 1905, missing.
[25] 33.84 in December, 1884, doubtful.

RECORDS OF PRECIPITATION IN CALIFORNIA—*Continued*

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Long Valley	4,400	....	May, 1909	....	....	8.99
Lordsburg	1,320	....	Jan., 1904	29.09	13.38	12.97
Los Alamos	600	....	Feb., 1909	....	....	7.53
Los Angeles	293	15.58	July, 1877	38.18	6.73	15.80
Los Baños	121	8.10	Jan., 1873	14.41	3.24	6.24
Los Burros	2,700	47.74	Sept., 1895–Dec., 1909	66.02	20.66	30.30
Los Gatos	600	33.33	Jan., 1885	67.22	15.18	27.66
Los Molinos	215	....	Oct., 1910	....	....	9.00
Los Vaqueros	950	20.89	Oct., 1902–March, 1910	29.90	13.19	12.20
Lowe Observatory	3,420	26.49	Jan., 1896	41.04	10.72	18.98[26]
Lytle Creek	....	....	Jan., 1906–Aug., 1910	....	....	22.37
McCloud	3,410	....	Sept., 1910	....	....	16.52
Macdoel	4,258	....	March, 1907	....	....	11.50
Madeline	5,270	....	Sept., 1908	....	....	5.30
Magalia	2,321	....	Jan., 1904	....	....	64.77
Mammoth Tank	257	2.00	Jan., 1878	7.85	T	5.40
Manzana	2,850	6.66	Jan., 1894–May, 1903	13.68	3.07	6.68
Maricopa	640	....	Sept., 1911	....	....	....
Mariposa	1,932	....	Sept., 1908	....	....	21.70
Marysville	67	20.59	Feb., 1871	38.91	8.15	14.36
Mecca	—185	....	Jan., 1906	....	....	....
Melones	775	....	Jan., 1907	....	....	21.66
Mendota	177	6.60	Feb., 1894–Nov., 1908	10.85	3.62	3.89
Menlo Park	64	16.85	Jan., 1878	30.39	9.28	14.76
Merced	173	10.70	Jan., 1872	22.08	3.20	8.00
Merced Falls	351	....	Jan., 1907	....	....	11.05
Mesa Grande	3,350	....	Oct., 1908	....	....	15.65
Middlewater	803	....	Oct., 1911	....	....	....
Mill Creek 1	2,500	....	Jan., 1907	....	....	31.77
Mill Creek 2	2,950	24.26	Jan., 1903	32.69	15.69	12.90
Mills College	200	26.70	Jan., 1893	37.19	14.44	16.24
Milo	1,600	24.60	April, 1898	42.06	13.65	19.10
Milton (near)	660	23.31	Jan., 1890	32.31	13.00	17.45
Modesto	90	10.52	Jan., 1871	19.04	3.87	5.98
Mojave	2,751	4.94	Jan., 1877	12.47	T	7.30
Mokelumne Hill	1,550	32.55	Jan., 1882	54.59	18.23	23.01
Mono Ranch	3,210	33.93	Jan., 1902	55.82	14.78	25.76
Montague	2,450	12.16	June, 1888	24.19	5.63	6.05[27]
Monterey	15	16.70	Jan., 1878	29.80	6.95	11.69[28]
Monterio	4,500	19.11	May, 1899	25.64	11.68	9.60
Montgomery Creek	2,500	....	Oct., 1908	....	....	33.87
Monumental	....	113.35	Aug., 1904–Oct., 1910	124.00	100.14	43.84

[26] December, 1902, to June, 1904, missing.
[27] 1901 and 1902 missing.
[28] 1847 to 1878 broken record.

RECORDS OF PRECIPITATION IN CALIFORNIA—*Continued*

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Morgan Hill	....	22.95	Feb., 1899	33.54	17.13	13.50[29]
Mountain View	95	15.55	Jan., 1886	31.15	7.12	11.06[30]
Mount Tamalpais	2,375	28.89	July, 1898	36.92	19.37	15.63
Mount St. Helena	2,300	61.59	Jan., 1901–Nov., 1912	79.56	33.13	40.33
Napa City	20	27.99	Jan., 1878	45.98	16.65	15.93
Napa, S. H.	60	24.32	Jan., 1877	48.29	13.30	15.04
Needles	477	3.52	Jan., 1892	12.48	.50	7.21
Nellie	5,350	....	Oct., 1901	....	....	36.88[31]
Nevada City	2,580	55.32	Jan., 1864	115.26	29.70	41.95[32]
Nevis	....	....	Jan., 1911	....	....	21.55
New Almaden	340	22.83	Jan., 1887–Dec., 1904	45.06	12.18	12.01
Newcastle	970	33.57	Jan., 1892–April, 1911	48.05	20.78	23.93
Newhall	1,200	16.89	Jan., 1877	42.11	5.44	15.70
Newman	91	11.17	Jan., 1889	23.67	4.88	7.27
Niles	87	19.87	Jan., 1886	35.91	9.34	13.31
North Bloomfield	3,200	57.58	Jan., 1871	77.84	22.97	37.21[33]
North Fork	3,000	....	March, 1904	....	....	23.15[34]
North Lakeport	1,450	31.02	Jan., 1901	43.15	19.22	23.48[35]
North San Juan	2,130	48.93	Jan., 1907–Dec., 1903	57.00	30.82	19.50
Oakdale	156	15.50	Jan., 1893	22.62	7.21	8.63
Oak Grove	2,751	....	Feb., 1910	....	....	9.53
Oakland	36	24.54	Jan., 1874	45.71	11.58	15.35
Oakville	153	....	April, 1906	....	....	23.77
Oceanside	60	....	Oct., 1909	....	....	5.78
Ojai Valley	900	....	May, 1905	37.44	....	17.59
Oleta	1,510	36.63	Jan., 1892–April, 1902	53.24	20.12	16.55
Orland	254	18.23	Jan., 1883	29.18	7.89	11.31
Orleans	520	54.65	April, 1903	81.93	42.01	24.27
Oroville	250	28.40	Jan., 1885	49.64	17.44	15.64
Ozena	3,680	....	Jan., 1904	31.41	....	11.59
Palermo	213	24.88	Jan., 1892	32.10	10.94	13.62
Palm Springs	584	4.01	Jan., 1889	9.35	....	7.44
Parkfield	2,800	....	Sept., 1907	27.42	....	13.61
Pasadena	827	14.53	Jan., 1893	24.15	6.64	11.83
Paso Robles	800	16.04	Jan., 1887	30.57	4.77	12.05
Peachland	190	43.99	Jan., 1896	63.65	24.89	29.89
Penstock Camp	3,750	....	March, 1907–Sept., 1910	....	....	24.04

[29] 1905 missing.
[30] 1905 missing.
[31] September, 1902, to June, 1904, April, 1907, to January, 1908, missing.
[32] September to December, 1886, missing.
[33] April 10, 1886, to March 10, 1896, missing.
[34] July to December, 1912, missing.
[35] June, 1905, to April, 1906, missing.

RECORDS OF PRECIPITATION IN CALIFORNIA—*Continued*

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Phoenix Dam	2,500	....	Nov., 1908	....	....	17.14
Pilot Creek	4,000	70.55	April, 1894	95.54	37.46	50.25
Pinchot	2,924	....	March, 1909	....	....	9.69
Pine Crest	1,000	25.47	Jan., 1898	45.38	14.22	19.04
Pittville	3,600	....	Sept., 1908–May, 1910	....	....	8.60
Placerville	1,875	44.62	Jan., 1874	78.13	21.55	28.76
Point Lobos	250	18.88	Jan., 1893	25.57	11.41	13.06
Point Loma	302	....	Jan., 1904	13.67	8.68	5.03
Point Reyes	490	24.02	Jan., 1892	31.33	13.95	9.78
Porterville	464	10.02	Jan., 1889	17.90	5.51	6.59
Poway	460	13.29	Jan., 1879–Aug., 1909	29.45	7.96	12.65[36]
Priest Valley	2,240	19.89	Sept., 1898	32.57	13.83	13.77
Quincy	3,400	48.21	April, 1895	73.22	28.53	35.17
Red Bluff	307	26.11	Feb., 1872	41.87	14.69	20.71
Redding	552	38.72	Jan., 1875	68.55	15.66	24.28
Redlands	1,352	14.96	Jan., 1889	25.78	6.30	13.72
Reedley	247	11.89	Aug., 1899	18.12	7.01	5.66
Represa	305	26.35	March, 1893	43.12	13.77	20.35
Rialto (near)	2,250	....	Aug., 1905	48.16	....	21.32
Rio Vista	35	18.02	Jan., 1893	25.42	8.78	12.48[37]
Riverside	851	10.59	Jan., 1881	22.74	2.94	7.94
Rocklin	249	22.28	Feb., 1870	38.63	10.71	20.12[38]
Rohnerville	75	45.16	April, 1901	61.49	35.08	21.18[39]
Rosewood	865	26.40	Jan., 1894–Oct., 1904	34.71	12.90	14.38
Ruth	....	....	June, 1912	....	....	....
Sacramento	71	19.56	July, 1849	36.35	4.71	15.04
St. Helena	255	....	Nov., 1907	....	....	27.64
Salinas	40	14.14	Jan., 1873	27.59	4.44	8.77
Salton	—263	2.93	Jan., 1889–July, 1907	9.29	T	5.12
San Bernardino	1,054	15.97	Jan., 1871	37.51	7.49	12.20
San Diego	93	9.62	Jan., 1850	25.99	3.75	9.05
San Francisco	207	23.25	July, 1849	49.27	7.42	24.36
San Jacinto	1,550	12.65	Oct., 1892	18.59	7.90	7.81
San José	95	14.79	Jan., 1874	30.30	4.83	12.38
San Leandro	48	23.83	Jan., 1895–Sept., 1911	29.92	12.97	16.72[40]
San Luis Obispo	201	21.52	July, 1869	42.40	7.20	17.00
San Mateo	22	21.18	Jan., 1874	40.82	7.34	16.14
San Miguel	616	11.22	Jan., 1887	20.13	3.47	8.84
San Miguel Island	500	14.51	March, 1894	25.49	5.65	10.44
Sanger	371	10.67	Jan., 1889	17.79	5.58	6.41

[36] 1887 to 1892 missing.
[37] February to December, 1907, missing.
[38] 1900 and 1901 missing.
[39] 1906 and 1907 broken record.
[40] 1907 and 1908 broken record.

RECORDS OF PRECIPITATION IN CALIFORNIA—*Continued*

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Santa Ana River	2,850	......	Jan., 1904	40.61	......	15.71
Santa Barbara	130	18.14	Jan., 1868	36.29	4.49	15.67
Santa Clara	90	16.42	Jan., 1881	31.20	7.86	12.72[41]
Santa Cruz	20	28.06	Jan., 1878	54.68	12.49	[illegible]
Santa Margarita	996	28.53	Feb., [illegible]	49.79	8.44	18.38
Santa Maria	220	14.59	Jan., 1886–Sept., 1912	27.81	5.70	10.31
Santa Monica	110	14.85	Jan., 1885	24.68	7.00	11.61[42]
Santa Paula	286	14.77	Jan., 1889	32.47	5.79	16.45
Santa Rosa	181	32.07	Jan., 1889	56.06	20.71	18.45
Sausalito	5	....	Jan., 1904	....	......	16.55
Selma	311	8.79	Jan., 1886	15.23	3.96	5.26
Seven Oaks	5,000	....	Jan., 1910	....	......	13.60
Shasta	1,049	56.99	Jan., 1896–Aug., 1912	78.60	25.37	35.96
Shingle Springs	1,415	34.99	Sept., 1849–June, 1912	79.24	14.60	34.13[43]
Sierra Madre	1,400	23.77	Jan., 1897	38.86	9.54	14.97
Sierraville	5,000	......	Nov., 1909	......	......	17.46
Sisquoc Ranch	600	......	Jan., 1904	34.52	....	15.80
Sisson	3,555	39.69	Jan., [illegible]	73.47	15.97	21.73
Snedden Ranch	4,900	11.59	July, 1893–July, 1907	23.50	4.14	13.50
Soledad	188	9.23	Jan., 1874	16.26	2.65	8.94
Sonoma	30	28.08	Jan., 1886–July, 1907	53.24	18.39	12.86[44]
Sonora	1,825	37.11	Sept., 1887	67.39	19.72	21.30[45]
Southeast Farallon	10	17.86	Jan., 1891	25.12	9.11	9.07[46]
Spreckels	43	....	Jan., 1905	21.57	....	6.81
Springville	4,000	......	Oct., 1907	....	......	[illegible]
Squirrel Inn	5,280	....	Jan., 1893	55.69	......	20.85[47]
Stanwood	2,140	......	Jan., 1904	97.78	......	46.39
Stirling City	3,525	....	Jan., 1904	125.20	....	51.63
Stockton, S. H.	23	14.63	Jan., 1867	22.49	6.73	11.49
Storey	296	9.66	June, 1899	13.69	6.18	5.92
Suisun	20	20.53	Jan., 1881	39.38	11.38	12.30
Sulphur Banks	1,350	......	July, 1911	......	......	......
Summerdale	5,270	56.44	Jan., 1896–Sept., 1912	85.46	29.34	39.08
Summit	7,017	47.45	Jan., 1871	80.10	21.08	30.40
Susanville	4,195	21.67	Oct., 1888	36.26	12.24	12.30
Tamarack	8,030	59.37	March, 1899	93.99	33.36	39.80[48]
Tehachapi	3,964	10.62	Jan., 1877	20.89	3.70	8.88
Tehama	220	20.27	Jan., 1871	51.98	5.95	16.58
Tequesquita Rancho	244	16.54	March, 1899–Dec., 1906	22.67	13.25	8.23

[41] 1886 missing.
[42] 1900 to 1902 missing; 1905 broken record.
[43] April, 1886, January, 1901, to January, 1906, missing
[44] 1894
[45]
[46] 1892 and 1898 broken record.
[47] January, 1899, to November, 1909, missing.
[48] September, 1902, to January, 1906, missing.

RECORDS OF PRECIPITATION IN CALIFORNIA—*Concluded*

Stations	Elevation Feet	Average seasonal	Period of record	Greatest seasonal	Least seasonal	Greatest monthly
Three Rivers	870	....	Aug., 1909	....	....	8.69
Towle	3,704	58.77	Jan., 1890	78.18	33.29	29.86
Tracy	64	10.58	Jan., 1879	21.92	4.91	7.21
Tejon Rancho	1,500	10.99	Sept., 1898	13.65	8.98	6.03[49]
Truckee	5,819	27.21	Feb., 1870	54.84	9.35	20.50
Tulare	289	9.01	March, 1874	15.31	3.07	5.85
Tulare (near)	274	7.66	Jan., 1893–Oct., 1909	13.97	5.13	4.99
Tustin (near)	200	13.33	Jan., 1877	32.65	5.75	12.13
Ukiah	620	37.30	Jan., 1877	60.48	19.83	30.75
Upland	1,750	20.77	July, 1891–Nov., 1911	33.23	8.37	14.03
Upper Lake	1,350	27.99	Jan., 1886	42.70	14.80	21.34
Upper Mattole	244	87.09	Jan., 1887	134.92	48.38	47.84
Vacaville	175	27.64	Jan., 1880	50.05	12.77	21.25
Valley Springs	673	24.61	Jan., 1888	38.15	12.34	18.52
Ventura	50	16.02	Jan., 1892–March, 1910	36.13	5.22	14.01[50]
Visalia	334	10.41	Jan., 1888	15.65	3.95	6.20
Walnut Creek	75	21.44	Jan., 1887–Dec., 1900	31.37	10.49	11.05
Warner Springs	3,165	....	April, 1906	23.23	....	7.93
Wasco	336	5.66	July, 1899	9.08	4.11	3.53
Wasioja	2,150	20.78	Jan., 1904–Dec., 1907	25.38	15.97	12.58
Watsonville	23	23.85	Feb., 1899	44.90	12.73	14.10
Weaverville	2,162	39.03	Jan., 1871	67.04	21.06	19.83[51]
Weitchpec	1,700	....	Jan., 1910	....	....	20.75
Weldon	2,700	8.64	Nov., 1899–Dec., 1906	10.65	9.46	4.51[52]
West Branch	3,216	....	Feb., 1907	....	....	63.71
Westley	90	10.65	Jan., 1889	17.01	4.18	5.70
West Point	2,326	44.26	Jan., 1894	59.91	22.71	26.44
West Saticoy	150	14.96	Feb., 1892	25.32	5.25	11.01[53]
Wheatland	84	22.53	Jan., 1888	33.69	12.45	17.36
Willits	1,364	54.67	Jan., 1878–Feb., 1908	87.34	31.35	29.21
Willows	136	16.55	Jan., 1879	29.94	6.58	9.97
Wire Bridge	565	35.30	Jan., 1894–Aug., 1902	44.42	20.15	14.44
Woodland	63	18.16	Jan., 1873	30.69	6.43	11.52
Woodleaf	3,250	....	Sept., 1905–March, 1910	....	....	63.08
Woodside	428	....	Jan., 1905–Nov., 1907	....	....	16.03
Yorba Linda	....	....	Nov., 1912	....	....	....
Yosemite	3,945	....	Jan., 1904	49.55	....	24.62[54]
Yreka	2,635	17.65	Jan., 1872–Dec., 1906	30.50	10.20	11.78[55]
Zenia	2,960	78.76	Jan., 1902–April, 1905	107.30	63.31	31.88

[49] October, 1906, to April, 1909, missing.
[50] June, 1906, to January, 1907, missing.
[51] July, 1893, to April, 1912, missing.
[52] September, 1902, to January, 1904, missing.
[53] April to October, 1892, April to December, 1903, missing.
[54] October, 1905, to August, 1906, missing.
[55] April to December, 1909, December, 1902, to December, 1903, missing.

Transmitted May 2, 1913.

PLATE 21

Average annual rainfall in California, based upon records covering a period of thirty years

From Bulletin L, Climatology of California

PLATE 22

Comparative monthly distribution of rain at selected stations
1 inch equals 25.4 mm.

PLATE 23

Sea-level pressures and paths of low and high centers for March, 1904, a wet winter month, especially in northern California.

PLATE 24

Sea-level pressures and paths of low and high centers for March, 1906, a winter month in which the precipitation averaged five inches in excess of the normal for stations in California.

PLATE 25

Total precipitation during a dry winter month (January, 1902). The deficiency in rainfall was approximately 33,000,000 acre feet as determined from reports from 200 stations.

PLATE 26

Total rainfall during a wet winter month. There was an excess of approximately 43,000,000 acre feet.

PLATE 27, FIGURE 1

Normal wind directions and velocities over the Pacific Ocean for January and February

From Deutsche Seewarte Atlas (Dr. W. Köppen)

Arrows fly with the wind. The length of arrow denotes steadiness of wind, the breadth of the arrow the force on the Beaufort scale.

PLATE 27, FIGURE 2

Normal wind directions and velocities over the Pacific Ocean for July and August

From Deutsche Seewarte Atlas (Dr. W. Köppen)

Arrows fly with the wind. The length of arrow denotes steadiness of wind, the breadth of the arrow the force on the Beaufort scale.

PLATE 28

Ocean currents off the coast of California

Modified from Ocean Charts of U. S. Weather Bureau

UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY

Vol. 1, No. 5, pp. 241-246 April 7, 1914

TWENTY-FIVE-YEAR SYNOPSIS

METEOROLOGICAL OBSERVATIONS MADE AT BERKELEY FROM JULY 1, 1887, TO JUNE 30, 1912

BY
ARMIN O. LEUSCHNER

Regular meteorological observations were begun at the Students' Observatory of the University of California at Berkeley under the direction of Professor Frank Soulé in December, 1886. The observations have been continued under the direction of the writer until June 30, 1912, when the voluntary meteorological station was transferred from the Students' Observatory (Berkeley Astronomical Department) to the Department of Geography. A fifteen-year synopsis embodying the results of the observations from July 1, 1887, to June 30, 1902, is published in the *University Chronicle*, vol. V, no. 3, and a twenty-year synopsis embodying the results of the observations to June 30, 1907, was published in the *University Chronicle,* vol. X, no. 4. The present synopsis embodies the results of the observations from July 1, 1887, to June 30, 1912, and was compiled under the direction of the writer by Mr. W. F. Meyer.

During the twenty-five years or more of observation the observatory was equipped with a set of standard barometers and thermometers and a rain gage, and daily observations of the weather were made in accordance with the instructions of the United States Weather Bureau for voluntary observers. From time to time it has seemed desirable to increase the equipment and to extend the meteorological service, but this was found impracticable without interference with the regular astronomical work of the department. The separation of the meteorological

and astronomical work provides for a fuller development of meteorological science in the University under the able direction of Mr. W. G. Reed, and the results already published in this series amply justify the extension of meteorological work in the University.

The plan of the present synopsis is the same in every respect as that of the two previous synopses:

Temperature.—Experience has shown that the average temperature of a day approximates the average of the temperatures observed at 8 A.M. and 8 P.M. and the average is called the mean daily temperature. The maximum and minimum temperatures are observed daily by means of a maximum and a minimum thermometer.

The highest temperature during the twenty-five years was 101.1° F, on June 6, 1903; the lowest was 24.9°, on January 14, 1888. The mean highest temperature per year, i.e., the average of the highest temperatures observed in each of the twenty-five years[1] is 91.7°, while the mean lowest temperature is 31.7°. In an average year, therefore, we may expect 92° in the shade on the hottest day, and 32° on the coldest day, or a range during the year of 60°.

In order to give a clear idea of the weather conditions at different times of the year, twenty-five year averages have been drawn for each month, and are given in Table 1.

The average of the daily mean temperatures of a month we may call the monthly mean temperature, or the daily mean temperature for the month. The twenty-five year averages for each month of the year of these monthly mean temperatures are given in the first horizontal line of the temperature table—e.g., the mean temperature for July is 59.1°.

The annual mean temperature at Berkeley, based upon records covering twenty-five years is 54.0°.

The twenty-five year means of the highest and lowest daily average temperatures (i.e., mean of the morning and evening observations) during the whole month are given in the second and third lines. Thus for July the highest daily average and the lowest daily average temperatures are 67.4° and 55.2°, respectively. The fourth and fifth lines contain the mean highest and

[1] Omitting the year 1907–08, for which records are defective.

TABLE I

METEOROLOGICAL OBSERVATIONS—TWENTY-FIVE YEAR MEANS FROM JULY 1, 1887, TO JUNE 30, 1912

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Atmospheric Pressure (Inches)												
Mean barometer	29.989	29.936	29.942	29.998	30.074	30.120	30.088	30.077	30.028	30.024	29.956	29.948
Highest daily average	30.072	30.054	30.069	30.147	30.262	30.388	30.338	30.326	30.288	30.242	30.161	30.101
Lowest daily average	29.805	29.803	29.770	29.779	29.814	29.792	29.703	29.732	29.683	29.799	29.786	29.776
Highest barometer reading	30.098	30.082	30.101	30.211	30.304	30.433	30.365	30.356	30.319	30.268	30.189	30.130
Lowest barometer reading	29.779	29.776	29.731	29.740	29.766	29.731	29.641	29.675	29.611	29.762	29.705	29.742
Monthly range	0.319	0.306	0.370	0.471	0.538	0.702	0.724	0.681	0.708	0.506	0.484	0.388
Average Temperature (Degrees F)												
Mean temperature	59.1	58.8	59.8	57.8	52.8	47.6	46.6	48.7	50.1	53.0	56.0	58.9
Highest daily average	67.4	65.5	67.0	67.5	61.6	55.9	54.8	56.2	58.6	61.2	65.5	68.1
Lowest daily average	55.2	55.7	54.8	51.4	46.3	40.6	39.2	41.3	43.0	47.1	50.8	53.9
Monthly maximum temperature	83.8	81.2	84.4	83.1	71.2	62.1	61.0	65.9	70.5	76.2	82.3	85.0
Monthly minimum temperature	49.8	50.7	49.1	45.9	40.0	35.2	34.1	35.5	37.8	40.1	43.6	47.0
Monthly range	34.0	30.5	35.3	37.2	31.2	26.9	26.9	30.4	32.7	36.1	38.7	38.0
Mean of daily maximum temperature	70.1	69.1	69.7	67.2	61.1	54.5	53.4	56.8	58.8	63.1	66.2	70.5
Means of daily minimum temperature	53.5	54.0	54.1	52.4	47.8	42.9	42.2	44.1	45.3	47.1	49.5	52.3
Mean daily range	16.6	15.1	15.6	14.8	13.3	11.6	11.2	12.7	13.5	16.0	16.7	18.2
Greatest daily range	28.7	26.9	28.3	27.7	21.4	18.8	18.0	19.9	22.5	26.7	29.3	30.4
Least daily range	8.4	7.8	6.6	5.7	5.4	5.6	4.8	4.9	5.9	7.1	7.3	8.4
Rainfall (Inches)												
Rainfall, dew, and fog	0.02	0.04	0.57	1.48	2.54	4.20	5.81	4.15	4.95	1.49	1.15	0.22
Accumulated rainfall, dew, and fog since June 30	0.02	0.06	0.63	2.11	4.65	8.85	14.66	18.81	23.76	25.25	26.40	26.62
Relative Humidity (Per cent)												
Mean relative humidity	84.9	86.8	85.5	84.3	84.1	85.9	87.4	86.6	86.7	85.8	84.8	83.7
Maximum humidity	95.0	95.5	96.0	96.2	96.2	97.0	97.2	97.0	96.6	95.4	95.6	95.2
Minimum humidity	63.1	68.3	58.4	50.3	56.6	60.2	64.2	62.8	63.5	63.3	64.4	65.6
Monthly range	31.9	27.2	37.6	45.9	39.6	36.8	33.0	34.2	33.1	32.1	31.2	29.6
Maximum daily range	20.2	21.0	24.5	27.5	26.0	23.7	23.7	22.6	22.8	24.1	22.1	19.6
Minimum daily range	1.8	1.4	1.4	0.7	0.6	0.6	0.4	0.6	0.5	1.0	1.3	1.2
Weather												
Number of clear days	13	10	13	16	15	14	11	11	11	14	13	15
Number of fair days	7	8	8	7	6	8	8	7	8	7	7	7
Number of cloudy days	11	13	9	8	9	9	12	10	12	9	11	8
Number of foggy days	11	11	6	5	4	2	2	3	2	2	3	5
Number of days on which rain fell	1	0	3	5	7	10	12	9	11	6	5	2
Wind Observations												
Prevailing direction of wind	SW	SW	SW	SSW and N	SSE and N	SE and NE	SE and NE	SE and N	SE and SW	SSW and W	SW	SW

the mean lowest temperatures for each month during the twenty-five years. For example, the July mean highest and mean lowest temperatures are 83.8° and 49.8°, respectively, and the difference, 34.0° indicates the mean monthly range in temperature for the month. The seventh and eighth lines contain the mean daily maximum and the mean daily minimum temperatures for each month. These for July are 70.1° and 53.5° respectively. Their difference, 16.6°, gives the average range of temperature during a day in July. The last two lines give the twenty-five year means of the greatest and the least daily range for each month.

Atmospheric Pressure.—The highest barometer reading during the twenty-five years was 30.829 inches, on December 25, 1903, at 8 A.M., the lowest 29.196 inches, on February 22, 1891, at 9 P.M.[2] The means given in the pressure table were derived in the same way as those of the temperature table. Thus the daily mean atmospheric pressure for July is 29.939 inches (sea-level).

The annual mean atmospheric pressure is 30.019 inches (sea-level).

Relative Humidity of the Air.—If the humidity of the air at saturation is taken at 100 per cent, the average humidity for the twenty-five years is found to be 85.5 per cent. The first horizontal line of the table gives the average for a normal day of each month, etc. The humidity frequently reaches the maximum, 100 per cent, and rarely falls below 30 per cent. The minimum humidity for twenty-five years was 27.3 per cent, October 28, 1890, at 2 P.M. The lowest percentage is reached during the prevalence of dry winds, or "northers."

Rainfall.—The average rainfall, including dew and fog, is 26.62 inches. The greatest annual rainfall, 46.00 inches, occurred in 1889–90; the least, 14.41 inches, in 1897–98. The distribution of the rainfall during the year is easily seen from the table. The maximum rainfall observed in twenty-four consecutive hours was 4.16 inches, February 14–15, 1891. Snow rarely falls.

Wind.—The prevailing direction of the wind every month is given in the table. The west and southwest winds are usually cool and damp, and rarely exceed fifteen miles per hour; the south winds are generally warm and rainy, the northeast winds or "northers," hot and dry, with an estimated velocity of from

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[2] Formerly observations were made at 7 A.M., 2 P.M., and 9 P.M.

thirty-five to forty miles per hour. Fierce and cold winds generally come from the northwest.

TABLE II

TWENTY-FIVE YEAR ANNUAL MEANS FROM JULY 1, 1887, TO JUNE 30, 1912

North latitude	37° 52′ 23″.6
Longitude west from Greenwich	122° 15′ 40″.8
Height of cistern of barometer above sea	320 ft.
Atmospheric Pressure (Inches) Reduced to Sea-level	
Mean barometer	30.019
Highest daily average, December 25, 1903	30.740
Lowest daily average, February 22, 1891	29.296
Highest barometer, December 25, 8 A.M., 1903	30.829
Lowest barometer, February 22, 9 P.M., 1891	29.196
Twenty-five year range	1.633
Temperature (Degrees F)	
Mean temperature	54.0
Highest daily average, September 7, 1904	81.5
Lowest daily average, January 14, 1888	30.9
Maximum temperature, June 6, 1903	101.1
Minimum temperature, January 14, 1888	24.9
Twenty-five year range	76.2
Mean of daily maximum temperatures	63.4
Mean of daily minimum temperatures	48.8
Mean daily range	14.6
Greatest daily range, June 18, 1895	38.0
Least daily range, February 19, 1892	1.5
Rainfall (Inches)	
Mean	26.62
Relative Humidity (Per cent)	
Mean relative humidity	85.5
Maximum humidity, often	100.0
Minimum humidity, October 28, 1890, 2 P.M.	27.3
Twenty-five year range	72.7
Greatest daily range, January 15, 1888–January 28, 1895	52.0
Least daily range, 8 A.M. and 8 P.M., often	0.0
Weather	
Number of clear days	156
Number of fair days	88
Number of cloudy days	121
Total	365
Number of foggy days	56
Number of days on which rain fell	71

Weather in General.—Under this heading the days of the month are divided into three groups, "clear," "fair," and

"cloudy." The twenty-five year means are given in the table. In addition, the number of days on which fog or rain was observed is stated separately.

An inspection of the table shows that the mean temperature varies but little during the year. The maximum daily range of temperature is comparatively small during the minter months (about 19°), indicating a uniform winter climate.

Two-thirds of the days in a month are usually clear or fair. July and August have the greatest number of foggy days. Rain rarely falls during the months of June, July, August, and September.

Table II, page 245, gives the annual means and a synopsis of other data for the twenty-five year period.

In the Twenty-Year Synopsis attention was directed to the fact that the meteorological instruments were in too protected a location for an accurate determination of the maximum and minimum temperatures and of the daily variation. It was not deemed advisable, however, to ascertain the corrections to be applied to the daily observations until comparison could be made with instruments set up in a new and somewhat permanent location. About a year before the transfer of the voluntary station to the Department of Geography, a standard meteorological shelter was secured from the United States Weather Bureau and set up in a permanent location on the slope south of the Students' Observatory. This shelter was equipped with a duplicate set of instruments and observations were made according to the regular program with both sets of instruments, that is, in the old and in the new location for the purpose of ascertaining the systematic corrections to be applied to the whole series of observations in order to reduce them to the new location. These observations are being continued by Mr. Reed, whose program includes the determination of the systematic corrections referred to. These corrections are, of course, not to be interpreted as signifying errors in the long and valuable series of observations made at the Students' Observatory, but they will make possible the use of this series in connection with the observations which are now being secured in the new location.

Transmitted January 23, 1914.

UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY

Vol. 1, No. 6, pp. 247-306, plates 29-31 April 7, 1914

REPORT

OF THE

METEOROLOGICAL STATION AT BERKELEY, CALIFORNIA,

FOR THE

YEAR ENDING JUNE 30, 1913

BY

WILLIAM GARDNER REED

CONTENTS

I. STATION REPORT

INTRODUCTION

On July 1, 1912, the Meteorological Station maintained by the University of California came under the direction of the Department of Geography, after having been conducted as a part of the work of the Students' Observatory (Berkeley Astronomical Department) since October 16, 1886.[1] At the time of the transfer the equipment consisted of the following instruments:

Maximum and minimum thermometers, U. S. Weather Bureau pattern.

Wet and dry bulb thermometers, U. S. Weather Bureau pattern.

Mercurial barometer (Fortin cistern), James Green.

Rain-gage, former U. S. Weather Bureau pattern.

The thermometers were exposed in a window shelter on the north side of the observatory building (see B in fig. 1, p. 249); a second set had been exposed in a United States Weather Bureau co-operative observer's shelter (see A in figure 1, and also plate 29) since April 1, 1912, for a comparison of exposures; the barometer was hung in an old-style United States Weather Bureau barometer box in an unheated room of the observatory; the rain-gage was exposed on the roof of the building four and a half meters (fifteen feet) above the ground (see C in fig. 1 and pls. 29 and 30).

Observations were made twice daily, at 8 A.M. and 8 P.M. Pacific Standard (120th Meridian) Time, as follows:

1. Temperature of the air (dry-bulb thermometer).
2. Temperature of evaporation (wet-bulb thermometer).
3. Pressure of the air.
4. Amount of cloud.
5. Wind direction and velocity on the Hazen (?) scale.
6. Precipitation in the preceding twelve hours.

At the evening observation the following additional factors were recorded:

7. Maximum temperature in the preceding 24 hours.

[1] The Station has been constantly under obligation to Professor Alexander G. McAdie, Section Director of the United States Weather Bureau, for advice and assistance.

8. Minimum temperature in the preceding 24 hours.
9. Prevailing wind direction of the day.
10. General character of the day.

Instruments and Exposures, 1912–1913

No immediate change was made in station equipment or in station routine at the time of the transfer to the Department of Geography, except that the temperature readings from the

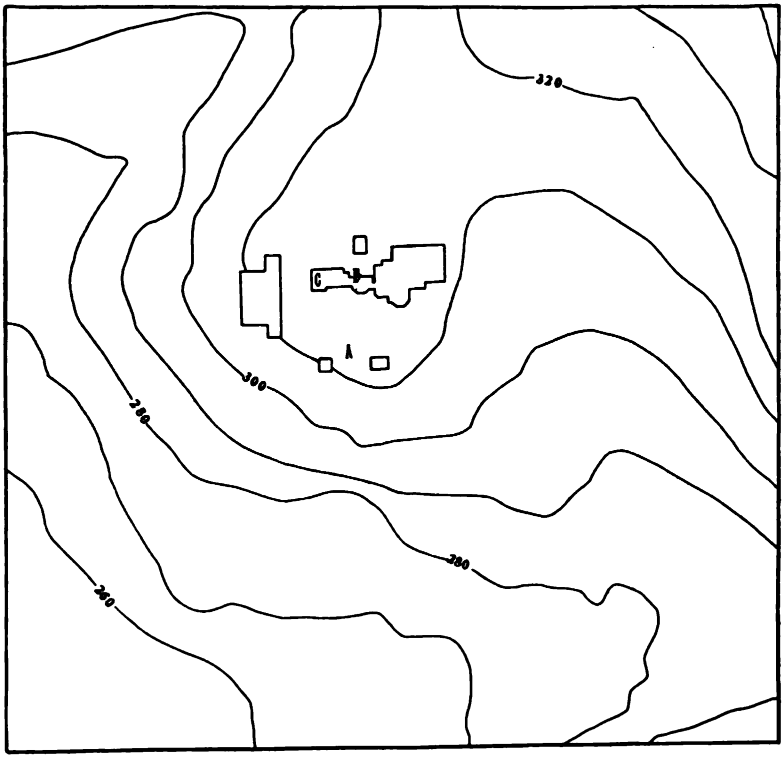

Fig. 1.—Map of a portion of the Campus of the University of California, Berkeley, showing the location of the meteorological instruments at the Students' Observatory. Scale about 1:2200, contour interval 10 feet, 3 meters. From map by George B. Sturgeon, 1908. A, United States Weather Bureau, Co-operative Observer's Shelter, containing wet and dry, and maximum and minimum thermometers, thermograph, and hygrograph. B, window shelter from which readings were made previous to July 1, 1912, containing wet and dry, and maximum and minimum thermometers. C, location of rain-gage, on roof of building about 4.6 meters. 15 feet, above the ground.

Weather Bureau shelter have been adopted as the standard temperatures for the station. The observation of the instruments in the window shelter has been continued; a comparative study of the temperatures observed under the two conditions of exposure is in progress and the results will be published as soon as is practicable.

During the year the following new equipment has been added:

July 1, 1912, Mercurial barometer, Fortin cistern, United States Weather Bureau pattern (Green), mounted in Weather Bureau barometer box.
Aneroid barograph, standard size (Short and Mason).

August 8, 1912, Thermograph, standard size (Richard)
Hygrograph, standard size (Richard).

August 9, 1912, Terrestrial radiation thermometer (Casella).

Besides the instruments in service the station is provided with one extra thermometer of each type, exposed, maximum and minimum.

The barometer and barograph are exposed in the Geography Laboratory in Bacon Hall, where the light and other conditions of exposure are satisfactory. The elevation of the cistern of the mercurial barometer was determined on August 17, 1913, by Mr. George B. Sturgeon to be 98.04 meters (321.65 feet) above the base to which the elevations on the University Campus are referred; this base is stated as "sea-level," but there is no more definite statement than that and there is some doubt as to its accuracy, although the elevation is certainly accurate enough for the purpose of reduction of air pressure, the error in elevation being less than a third of a meter (one foot).

The thermometers, thermograph and hygrograph are exposed in the Weather Bureau shelter (at A in figure 1) which is about twenty meters (sixty-five feet) south of the main building of the Observatory, between two smaller buildings, which are about five meters (fifteen feet) high, but as there is about six meters (twenty feet) between the shelter and the nearer of the buildings they probably do not seriously impair the record. The shelter is situated at the edge of a steep slope which leads to a valley crossing the Campus and which probably represents a line of air drainage. The general location of the instruments at the

Observatory is shown by the map, figure 1, and the photographs, plates 29 and 30. The shelter is not as large as it should be to protect the instruments properly. Besides this, it is badly crowded, as it was constructed to contain only a maximum and a minimum thermometer and it now contains in addition a wet and dry bulb thermometer and two recording instruments.

The rain-gage exposure has not been changed from that of the preceding year; the gage is exposed on the roof of the western end of the main observatory building (see C in figure 1, and plates 29 and 30) at an elevation of about 4.6 meters (15 feet) above the ground. The area of this part of the roof is about twenty-five square meters (two hundred and seventy-five square feet). The roof immediately to the east is 1.2 meters (4 feet) higher at its ridge, but has the same elevation at the edge as the flat roof on which the gage is exposed. The sheltering effect of this roof and the surrounding trees is probably more a benefit in decreasing wind velocity and thus tending to bring the catch of the gage up to the true rainfall, than it is a detriment in directly sheltering the gage from the rain. However, an exposure on the ground is to be desired.

Observations and Records, 1912–1913

During August, 1912, slight changes were made in the station routine to give more complete records. The observations since that time made at 8 A.M. and 8 P.M., Pacific Time, have been as follows:

1. Temperature of the air (dry-bulb thermometer).
2. Temperature of evaporation (wet-bulb thermometer).
3. Maximum temperature in the preceding 12 hours.
4. Minimum temperature in the preceding 12 hours.
5. Pressure of the air.
6. Amount of cloud, and weather.
7. Wind direction and estimated velocity.
8. Precipitation in the preceding 12 hours.

In addition to the observations at the regular hours, a record has been kept of the general character and prevailing wind direction of each day, the times of beginning and ending of

precipitation, of the occurrence and character of fog, and of the occurrence of frost; an attempt has been made to record occasional meteorological phenomena of interest. The recording instruments have furnished continuous records of air temperature, air pressure, and relative humidity; these automatic records are complete from the times of the installation of the instruments and are correct except for such errors as are inherent in the instruments and which are not large.

The results of the observations have been recorded as made upon blank forms of the United States Weather Bureau. In addition to the figures obtained by observation, the following have been computed for each observation: air pressure, corrected for temperature and local gravity; air pressure at sea-level; dew-point; relative humidity; and pressure of aqueous vapor. The range of temperature and the mean temperature for each day, the change from the mean of the preceding day, and the total precipitation for each day have been computed.

The observations and computing, and the publication of the results have been under the immediate direction of the writer. The observations were made by the following observers during the periods stated:

July 1 to August 26, A. F. Hurd.
August 26 to December 31, F. A. Shaeffer.
January 1 to January 12, S. B. Nicholson.
January 13 to May 7, F. A. Shaeffer.
May 7 to May 15, S. B. Nicholson.
May 15 to June 15, J. E. Krueger.
June 15 to June 30, F. A. Shaeffer.

Occasional single observations have been made by the writer and all questions of method and policy have been referred to him. As far as practicable the regulations of the United States Weather Bureau have been followed.

REPORTS AND PUBLICATIONS, 1912–13

The regular form of co-operative observers report has been prepared and sent to the office of the United States Weather Bureau at San Francisco at the end of each month. This report

includes the daily maximum and minimum temperatures, amount and duration of precipitation, prevailing wind direction and general weather of each day. The following printed summaries have been issued from the station during the year:

Monthly Meteorological Synopsis of Berkeley, 2nd Series, vol. 1, no. 1, July, 1912, to 12, June, 1913.

Monthly and Annual Meteorological Summary of Berkeley, in University of California Chronicle, vol. 15, pp. 156–157, Berkeley, 1913.

Monthly and Seasonal Meteorological Summary of Berkeley, *ibid.*, pp. 407–408, Berkeley, 1913.

The following articles have appeared under the name of W. G. Reed:

Meteorological Observations at the University, University of California Chronicle, vol. 15, pp. 152–155, Berkeley, 1913.

Meteorological Observations at the University of California, Science, New Series, vol. 38, pp. 800–803, New York, 1913.

Niederschlag von Berkeley (Kalifornien), Meteorolog. Zeitschr., vol. 29, pp. 526–528, Braunschwieg, 1912.

Rainfall of Berkeley, California, Univ. Calif. Publ. Geog., vol. 1, pp. 63–79, Berkeley, 1913; in briefer form, Mo. Wea. Rev., vol. 41, pp. 625-627, Washington, 1913.

II. BERKELEY METEOROLOGY, 1912–13

INTRODUCTION

A monthly and seasonal summary of the meteorological conditions as recorded by the observations made at the station maintained by the Department of Geography of the University of California on the campus at Berkeley is presented in Table I on pages 258 to 263. The table includes the usual statements of means and extremes with dates, which have been suggested by the International Meteorological Committee and which have been adopted by a majority of meteorological stations for their reports; in addition certain other data which have appeared to be of interest and value as judged by the Monthly Meteorological Synopsis of Berkeley have been included in the table. It is intended that an annual report of meteorological conditions at Berkeley shall be issued each year, so that the report for the year ending June 30, 1913, is the first of a series. For this reason the rational meteorological units of the C.G.S. system have been used, as these units have been advocated by international committees in various branches of meteorology and by the more progressive meteorologists; that they have not been more widely

[2] The meteorological units used in this report are defined as follows:

Bar, a pressure equal to an accelerating force of one megadyne (1,000,000 dynes) per square centimeter.

Millibar, a pressure equal to one-thousandth of a bar, that is, one kilodyne (1000 dynes) per square centimeter.

Dyne, a force which acting for one second will impart to a mass of one gram a velocity of one centimeter per second.

Absolute temperature, the number of degrees above absolute zero in units whose length is one one-hundredth of the difference between the boiling point of pure water and the melting point of pure ice under standard conditions. In this system the melting point of ice is 273° A.

For discussions of the absolute units see:

McAdie A. G., New Units in Aero-physics, Am. Jour. Sci., Ser. 4, vol. 30, pp. 277–282, 1910. (Contains bibliography.)

Shaw, W. N., Forecasting Weather (London, 1911), Introduction; Observer's Handbook, Meteorological Office, 1910 (London, 1911), Appendix iii.

Bjerknes, V., Millimeter oder Millibar, Meteorolog. Zeitschr., vol. 29, pp. 576–578, 1912; Das C.G.S.-System und die Meteorologie, *ibid.*, vol. 30, pp. 67–71, 1913.

Since this report was submitted for publication Professor C. F. Marvin, Chief of the U. S. Weather Bureau, has issued the following statement in

adopted as yet is due to the necessity in changing existing records, a consideration which has no weight at the beginning of a series of reports.[2] For the convenience of those who are not familiar with the C.G.S. units the English equivalents have also been given.

In addition to the table, extracts from the monthly reports have been revised and will be found on pages 264 to 270. The table and the extracts are intended to give in summarized form a statement of the more important meteorological conditions for the year. The conditions under which the observations were made and the data compiled, as well as some discussion of the significance of the different data and such comparisons as seemed desirable, together with graphic representations of the more important elements, are included in the succeeding pages.

LOCATION OF INSTRUMENTS

The meteorological summary for the year ending June 30, 1913, which is given in Table I on pages 258 to 263, is based on observations made twice daily on the University Campus at Berkeley. The general location of the Campus with reference to San Francisco Bay and the Berkeley Hills is shown by plate 31, which is from a photograph of a model of the Bay Region made for the Spring Valley Water Company.[3] The Campus is marked on the photograph by the letter C. The general location of the region is to the east of San Francisco Bay, about nineteen kilometers, twelve miles,[4] from the Golden Gate and the Pacific Ocean. The slope from the Campus to San Francisco Bay is

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regard to the use of the C.G.S. units for the weather map of the Northern Hemisphere, publication of which was begun by the Weather Bureau in January, 1914:

"In beginning this important publication it seemed advisable not to retain the arbitrary and irrational units ordinarily employed for measuring pressure and temperature of the atmosphere, but to adopt the more scientific and rational units of the C.G.S. system. Accordingly, the reported pressures are all expressed in dynamic units in which a pressure of 750.06 mm. of mercury corresponds to a force of 1,000,000 dynes. Following the suggestion of Bjerknes, this absolute unit of pressure is called 1 bar = 1000 millibars. The reported temperatures have all been reduced to the absolute scale (Centigrade) on which the temperature of melting ice is 273°. Mathematical and dynamic studies of the motions of the atmosphere are possible only when the data are given in rational units of the kind described."

gentle, about ninety meters, three hundred feet, in three kilometers, two miles. To the east the Berkeley Hills rise abruptly to elevations of over 300 meters, 1000 feet, above sea-level.

The more local topographic features of the University Campus are shown by figure 2, below, which has been reduced from the architect's plan of the University grounds and buildings. The topographic relations, which may be of some importance from a meteorological standpoint, may be seen from this map. The thermometer shelter and the rain-gage are located at the Students' Observatory, O in figure 2. This is on the west side of a small hill. This location probably provides good air drainage, with the result that temperatures at the location of the thermometers are probably higher than those at the bottom of the valley a few hundred meters away.

The exact position of the instruments may be seen from figure 1, on page 249, which is a portion of the map from which figure 2 was drawn. The buildings of the Students' Observatory are

Fig. 2.—Map showing the topography of the Campus of the University of California. Scale about 1:9000, contour interval 10 feet, 3 meters. From map by George B. Sturgeon, 1908. O, location of the Students' Observatory, where meteorological instruments are exposed.

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[3] The writer wishes to express his thanks for this photograph to Mr. S. P. Eastman of the Spring Valley Water Company.

[4] Conversions made by use of Smithsonian Meteorological Tables, 3rd Revised Edition, Washington, 1907.

shown on this plan; they are all one-story structures, although there are telescope domes on all of them. The photographs, plates 29 and 30, show the relations of the instruments to the buildings. In figure 1 the locations of the instruments are shown as follows: A, thermometer shelter, United States Weather Bureau co-operative observer's pattern (see pl. 29); B, window shelter where temperature observations were made prior to April 1, 1912, and where observations are being continued for comparison with the newer shelter; and C, the roof on which the rain-gage is exposed. The conditions of exposure are better shown in the photographs than is possible in a map; the thermometer shelter and the rain-gage are shown in plates 29 and 30; no photograph has been made of the window shelter, as the temperatures obtained there are not now under discussion. Pressure observations have been made during the year in Bacon Hall, which is about three hundred meters southeast from the Observatory.

TABLE I.—ABSOLUTE (C.G.S.) UNITS

Summary of Observations at Berkeley, California, for the Year Ending June 30, 1913

Latitude +37° 52′. Longitude 122° 16′ west from Greenwich. Height of barometer cistern above sea, 98 meters.
Height of thermometers above ground, 1.5 meters. Height of rain-gage above ground, 4.6 meters.
Observations at 8 h. and 20 h. Mean Civil Time of the 120th Meridian (4 h. and 16 h. Greenwich Mean Civil Time).

Atmospheric Pressure. Sea-level equivalents in bars

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air pressure at obs. hrs.	1.017	1.016	1.015	1.017	1.020	1.024	1.020	1.017	1.022	1.019	1.017	1.016	1.018
Maximum air pressure[1]	1.021	1.021	1.020	1.024	1.028	1.033	1.036	1.033	1.032	1.025	1.025	1.024	1.036
Date	14	13	16	28	12	26	8	13	15	6	10	19	Jan. 8
Hour (120th Meridian)	11	12	10	10	5	11	11	10	8	1	12	12	11
Minimum air pressure[1]	1.010	1.010	1.009	1.002	1.010	1.013	1.004	1.001	1.009	1.011	1.011	1.009	1.001
Date	9	16	17	4	2	14	15	25	11	13	30	26	Feb. 25
Hour (120th Meridian)	4	21	19	18	8	5	5	14	17	6	17	5	5

Air Temperature (in Absolute Degrees)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air temperature[2]	289.4	290.6	291.6	288.6	286.1	283.2	280.8	283.8	284.0	286.3	287.6	289.0	286.8
Mean air temperature at 8 h.	287.2	288.4	288.8	285.0	283.4	279.8	278.3	280.4	280.6	284.5	286.3	287.9	284.2
Mean air temperature at 20 h.	286.3	287.3	288.8	285.2	284.8	281.6	280.1	282.0	282.0	283.5	285.2	287.1	284.5
Mean maximum temperature	294.2	296.1	297.2	295.2	290.7	287.8	285.2	288.9	289.8	292.1	292.8	294.4	292.0
Mean minimum temperature	284.7	285.1	286.1	281.9	281.6	278.6	276.5	278.7	278.3	280.6	282.4	283.7	281.5
Highest daily mean	291.9	292.4	301.6	294.1	289.7	285.2	286.7	288.7	289.6	294.2	291.7	292.9	301.6
Date	16	7	18	14	7	18	31	15	8	24	30	30	Sept. 18
Lowest daily mean	286.3	288.6	287.6	284.4	282.0	280.1	275.3	278.6	278.9	282.9	284.8	284.7	275.3
Date	29	2, 21	3	24	29	24	5	23	23	6	6	6	Jan. 5

[1] From the barograph corrected.
[2] ½ (max. + min.).

TABLE I.—ABSOLUTE (C.G.S.) UNITS—*Continued*

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Maximum temperature	299.1	300.6	311.2	303.1	294.8	290.3	293.1	295.7	298.4	303.3	299.8	301.6	311.2
Date	16	7	18	13, 14	26	7	31	15	7	24	30	30	Sept. 18
Minimum temperature	281.9	282.4	282.0	279.2	278.8	274.8	270.6	273.5	274.6	276.9	279.2	280.6	270.6
Date	7	29	3	24	30	27	6	23	24	6, 28	13	9	Jan. 6
Monthly range	17.2	18.2	29.2	23.9	15.9	15.5	22.5	22.2	23.8	26.4	20.6	21.0	21.4
Mean daily range	9.6	11.2	11.4	13.2	9.2	9.3	8.9	10.2	11.5	11.4	10.4	10.7	10.6
Greatest daily range	14.4	16.4	19.5	20.2	14.4	11.9	14.6	14.0	20.0	19.3	16.4	17.4	20.2
Date	16	7	11	13	26	8	26	15	7	23	2	30	Oct. 13
Least daily range	3.4	7.8	3.4	7.3	2.8	5.9	2.4	5.4	2.5	4.6	5.3	3.0	2.4
Date	29	2	6	28	6	14, 17	13	8	10	3	27	6	Jan. 13
Mean change from day to day	1.1	1.2	2.7	1.2	1.4	1.1	1.5	1.6	1.7	1.7	1.2	0.9	1.4
Moisture													
Mean dew point at 8 h., °A	285	285	286	281	281	276	275	277	278	281	282	284	281
Mean dew point at 20 h., °A	285	286	286	281	281	277	276	279	279	280	282	284	281
Mean vapor pressure at 8 h., mb.	14	15	16	11	11	8	8	8	9	10	11	13	11
Mean vapor pressure at 20 h., mb.	14	15	16	11	11	9	8	9	10	10	12	13	12
Mean relative humidity at 8 h., %	86	83	85	79	86	78	83	81	85	79	79	78	82
Mean relative humidity at 20 h., %	90	92	87	79	81	76	79	82	82	81	86	84	83
Mean cloudiness at 8 h.	.8	.5	.5	.3	.4	.4	.5	.6	.6	.5	.6	.6	.5
Mean cloudiness at 20 h.	.5	.3	.5	.1	.2	.3	.3	.2	.3	.4	.5	.4	.3
Total precipit'n (rain, dew, fog), mm.[3]	.	.	37.1	17.8	98.8	41.2	96.0	16.3	50.3	14.5	25.2	.0.0	397.2
Maximum precipitation in 24 hrs., mm.[3]	.	.	22.9	7.4	60.7	17.8	20.8	9.4	21.3	5.1	10.4	.0.0	60.7
Date	....	....	6	25	6	16	15	24	18	3, 5	27	22	Nov. 6

[3] In accordance with the recommendation of the International Meteorological Committee, absence of precipitation is indicated by a dot (.); a trace, amount too small to measure, by the symbol .0.0.

TABLE Ia.—ENGLISH UNITS

Summary of Observations at Berkeley, California, for the Year Ending June 30, 1913

North Latitude 37° 52′. Longitude west from Greenwich 122° 16′. Height of barometer cistern above sea, 321 feet. Height of thermometers above ground, 5 feet. Height of rain-gage above ground, 15 feet. Observations at 8 a.m. and 8 p.m. Pacific Standard (120 Meridian) time.

Atmospheric Pressure (in Inches of Mercury)

Reduced to standard gravity and sea-level

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air pressure at obs. hrs.	30.02	29.98	29.96	30.03	30.13	30.23	30.14	30.04	30.18	30.08	30.03	29.98	30.07
Maximum air pressure[1]	30.17	30.16	30.12	30.24	30.36	30.50	30.58	30.51	30.45	30.26	30.25	30.23	30.58
Date	14	13	16	28	12	26	8	13	15	6	10	19	Jan. 8
Hour	11 a.m.	Noon	10 a.m.	10 a.m.	5 a.m.	11 a.m.	11 a.m.	10 a.m.	8 a.m.	1 a.m.	Noon	Noon	11 a.m.
Minimum air pressure[1]	29.82	29.84	29.79	29.61	29.84	29.91	29.66	29.57	29.79	29.85	29.85	29.78	29.57
Date	9	16	17	4	2	14	15	25	11	13	30	26	Feb. 25
Hour	4 a.m.	9 p.m.	7 p.m.	6 p.m.	8 a.m.	5 p.m.	5 a.m.	2 p.m.	5 p.m.	6 a.m.	5 p.m.	5 a.m.	2 p.m.

Air Temperature (in Fahrenheit Degrees)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air temperature[2]	61.5	63.6	65.6	60.0	55.6	50.3	46.2	51.4	51.8	56.0	58.4	61.0	56.7
Mean air temperature at 8 A.M.	57.5	59.8	60.6	53.6	50.7	44.2	41.5	45.3	45.7	52.7	55.9	58.7	52.2
Mean air temperature at 8 P.M.	55.9	57.8	60.6	54.0	53.2	47.5	44.7	48.2	48.2	50.9	53.9	57.3	52.7
Mean maximum temperature	70.2	73.5	75.6	71.9	63.9	58.6	54.0	60.6	62.2	66.3	67.7	70.6	66.2
Mean minimum temperature	53.0	53.8	55.6	48.1	47.4	42.0	38.3	42.2	41.5	45.7	49.0	51.3	47.3
Highest daily mean	66.0	66.9	83.5	70.0	62.1	54.0	56.7	60.2	61.9	70.2	65.6	67.9	83.5
Date	16	7	18	14	7	18	31	15	8	24	30	30	Sept. 18
Lowest daily mean	56.0	60.0	58.2	52.6	48.2	44.8	36.2	42.0	42.6	49.9	53.3	53.0	36.2
Date	29	2, 21	3	24	29	24	5	23	23	6	6	6	Jan. 5
Maximum temperature	79.0	81.7	100.8	86.2	71.2	63.2	68.2	72.8	77.8	86.6	80.2	83.5	100.8

[1] From the barograph corrected.

[2] ½ (max. + min.).

TABLE I*a*—ENGLISH UNITS—*Continued*

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Date	16	7	18	13, 14	26	7	31	15	7	24	30	30	Sept. 18
Minimum temperature	48.0	48.9	48.2	43.1	42.5	35.3	27.7	32.9	34.9	39.0	43.1	45.7	27.7
Date	7	29	3	24	30	27	6	23	24	6, 28	13	9	Jan. 6
Monthly range	31.0	32.8	52.6	43.1	28.7	27.9	40.5	39.9	42.9	47.6	37.1	37.9	38.5
Mean daily range	17.3	20.2	20.5	23.7	16.5	16.8	16.0	18.4	20.7	20.5	18.7	19.2	19.0
Greatest daily range	26.0	29.5	35.1	36.3	26.0	21.4	26.2	25.2	36.0	34.7	29.6	31.4	363
Date	16	7	11	13	26	8	26	15	7	23	2	30	Oct. 13
Least daily range	8.0	14.0	6.1	13.1	5.1	10.6	4.4	9.7	4.5	8.2	9.5	5.4	4.4
Date	29	2	6	28	6	14, 17	13	8	10	3	27	6	Jan. 13
Mean change from day to day	2.0	2.1	4.9	2.1	2.5	1.9	2.7	2.9	3.0	3.0	2.1	1.6	2.6
Moisture													
Mean dew point at 8 A.M., ° F	53	54	56	47	46	37	36	39	41	46	49	52	46
Mean dew point at 8 P.M., ° F	53	55	56	47	47	40	38	42	43	45	49	52	47
Mean vapor pressure at 8 A.M., in.	.406	.416	.446	.322	.316	.229	.222	.244	.261	.308	.342	.385	.325
Mean vapor pressure at 8 P.M., in.	.407	.435	.451	.326	.324	.254	.239	.272	.279	.305	.355	.389	.336
Mean relative humidity at 8 A.M., %	86	83	85	79	86	78	83	81	85	79	79	78	82
Mean relative humidity at 8 P.M., %	90	92	87	79	81	76	79	82	82	81	86	84	83
Mean cloudiness at 8 A.M.	.8	.5	.5	.3	.4	.4	.5	.6	.6	.5	.6	.6	.5
Mean cloudiness at 8 P.M.	.5	.3	.5	.1	.2	.3	.3	.2	.3	.4	.5	.4	.3
Total precipit'n (rain, dew, fog), in.[3]	.	.	1.46	0.70	3.89	1.62	3.78	0.64	1.98	0.57	0.99	.0.0	15.63
Maximum precipitation in 24 hrs., in.[3]	.	.	0.90	0.29	2.39	0.70	0.82	0.37	0.84	0.20	0.41	.0.0	2.39
Date	....	....	6	25	6	16	15	24	18	3, 5	27	22	Nov. 6

[3] In accordance with the recommendation of the International Meteorological Committee, absence of precipitation is indicated by a dot (.); a trace, amount too small to measure, by the symbol .0.0.

TABLE I (and I*a*)—*Continued*

Weather (Number of Days)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Clear	5	12	17	19	15	15	15	12	15	11	11	12	159
Partly cloudy	20	15	5	11	6	8	5	6	7	15	12	12	122
Cloudy	6	4	8	1	9	8	11	10	9	4	8	6	84
Days with fog[4]	3	3	8	1	5	2	5	6	5	1	0	1	40
Days with frost	0	0	0	0	3	13	12	4	5	0	0	0	37
Days with precip. >.25 mm. (.01 in.)	0	0	3	5	10	6	11	7	5	5	6	0	58
Days with precip. >1.0 mm. (.04 in.)	0	0	3	4	6	5	10	3	5	5	5	0	46
Longest period with precipitation	0	0	2	2	5	4	7	4	3	2	2	0	7
Longest period without precipitation	31	31	24	21	11	13	7	6	16	19	8	30	69[5]

Wind at 8 h. and 20 h. (Number of Observations)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
North	0	1	4	6	3	10	11	9	6	1	2	0	53
Northeast	0	0	0	0	0	2	1	3	0	0	2	0	8
East	0	0	1	0	0	1	1	4	0	0	0	0	7
Southeast	6	4	4	4	3	8	7	4	0	6	2	5	53
South	19	10	26	25	29	14	21	16	18	22	9	9	218
Southwest	15	18	13	9	7	9	4	4	18	10	14	23	144
West	8	7	6	6	7	1	2	4	3	7	3	5	59
Northwest	1	0	1	8	9	7	4	3	8	8	1	1	51
Calm	13	22	5	4	2	10	11	9	9	6	29	17	137

[4] Includes only days on which fog lay on the Campus. See International Meteorological Kodex, ed. 2, p. 18: "Fog is to be recorded only when the observer is enveloped in it."

[5] From the beginning of the summer rainless period, June 25, 1912.

TABLE I (and Ia)—*Concluded*

Prevailing Wind (Number of Days)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
North	0	0	1	2	1	4	7	2	3	1	0	0	21
Northeast	0	0	1	0	0	3	0	2	0	0	0	0	6
East	0	0	0	0	0	2	1	1	0	0	0	0	4
Southeast	1	0	0	0	0	1	2	3	0	0	0	1	8
South	11	4	5	2	8	14	10	2	4	0	4	4	68
Southwest	14	18	18	9	8	3	3	4	9	11	15	17	129
West	5	6	3	12	6	0	5	9	8	9	8	7	78
Northwest	0	3	1	6	6	3	2	5	6	9	2	1	44
Calm	0	0	1	0	1	1	1	0	1	0	2	0	7

EXTRACTS FROM THE MONTHLY REPORTS

July, 1912—There was more sunshine during this month than the record of the morning and evening observations shows. Twenty-two mornings were overcast, usually with a low stratus cloud sheet, locally known as "high fog"; this cloud sometimes becomes a true fog west of Berkeley. In most cases the sky cleared before 10 A.M. and remained clear into the evening or late afternoon, when the cloud was brought in from the ocean by the westerly winds. Fifteen evenings were cloudy at the time of observation. The sky was cloudy all day on July 10, 17, 28, and 29, and for the greater part of the day on July 31. The mean cloudiness at 8 A.M. was somewhat higher than the average, but the cloudiness for the whole day was about normal. Fog, as defined by the International Meterological Committee, occurred on the evening of the 31st, and in local streaks on the 9th and 29th. "High fog" was recorded on 17 days.

The temperature was about normal, but an impression of warmth was created by the amount of bright sunshine. The relative humidity for the month was about normal.

No precipitation of any kind was recorded.

August, 1912—The greater part of the daytime hours of this month were times of bright sunshine for that part of Berkeley in which the Campus is situated. The large number of partly cloudy days is due to the occurrence of "high fog" in the morning and evening hours. True fog occurred on three days, dense fog on the afternoon and evening of the 19th, and light fog on the afternoon and evening of the 2nd and the 12th. "High fog" was observed on eighteen days. The mean cloudiness for both morning and evening observation hours was considerably less than the average. This is due to the fact that the sky was practically cloudless at these hours in all cases where "high fog" was not present.

The mean temperature for the month was higher than the twenty-six year average. On account of the change in the exposure of the thermometers, those exposed under the old conditions indicated a mean temperature slightly below the average.

The wind was prevailingly from the west and south, as is usual at this time of the year. The number of observations of wind from the southwest was somewhat higher, and that of observations of wind from the west and south is somewhat lower than the average; this is due in part to the individuality of the observers, as no wind vane has as yet been procured for the station.

No precipitation was recorded during the month. The deficiency of 1.8 millimeters, 0.07 inch, since July 1 does not indicate an unusual condition. The average amounts of precipitation for both July and August are largely due to single heavy rains.

September, 1912, was a warm month. The mean temperature was 2.0° A, 3.6° F, higher than the average of the twenty-six years, and, even after correcting for the change in exposure, the temperature was

higher than the average. The highest temperature observed was 311.2° A, 100.8° F, at about 3 P.M. on the 18th, when there was a strong, hot wind from the northeast. At this time the relative humidity was about 15 per cent. This is the highest temperature recorded in Berkeley in September; but it cannot properly be compared with the maximum of the record, as the maximum thermometer exposed under the old conditions registered only 307.4° A, 94.0° F, and this temperature was exceeded in September, 1904. The other high temperatures of this month are in a large measure due to higher maxima resulting from the change in the exposure.

Cloudiness of 0.5 at the observation hours is the result of cloud cover over the whole sky at these hours for about half the time; this cloudiness was not a feature of the day as a whole. Light fog was observed on six mornings and two evenings; the so-called "high fog" was observed on three other days.

The first rain of the season fell on the 2nd, when 2.3 millimeters, 0.09 inch, was recorded. This is the tenth time in twenty-six years in which rain has occurred in the early days of September. Rain amounting to 34.8 millimeters, 1.37 inches, fell on the 5th and 6th, so that the total for the month was about three times the average for September. The maximum fall in twenty-four hours is stated as 22.9 millimeters, 0.90 inch, to 8 P.M. on the 6th, but the whole 34.8 millimeters fell between 12:55 P.M. on the 5th and 1:45 P.M. on the 6th.

The wind during the daytime hours was mainly from the southwest on seventeen days; wind from the south was recorded at the observation hours more often than that from any other direction, but this is subject to error because of the lack of a vane.

OCTOBER, 1912, was a month of bright sunshine and prevailingly clear skies. Only one whole day was recorded as cloudy. At the morning observation hour on nine days the sky was cloudy, but this condition did not last through the day, and in three of these cases the general character of the day was clear. Fog occurred but once, for about two hours on the evening of the 28th.

Although the mean temperature for the month was recorded as normal, it was, in fact, about 1.5° A, 3° F, cooler than the average of the twenty-six years, as was shown by the temperatures from the window shelter: the mean temperature was 287.0° A, 57.2° F, while the mean from the standard shelter was 288.6° A, 60.0° F. The difference in the temperatures under the different conditions of exposure was most marked during the warmer hours; the night temperatures from the two exposures were not far different. The greatest daily range was 20.2° A, 36.3° F, a new record for October, but one which is undoubtedly due to the change in the exposure.

The wind for the greater part of the time was westerly, varying from northwest to southwest. The velocity seldom exceeded seven meters per second (15 miles per hour), and was generally much below this. Southerly winds or light airs were most usual at the times of observation. The amount of calm recorded was less than the average, but this is probably due to a more restricted use of the term.

The first part of the month was rainless, no precipitation being recorded until the 22nd, which was the only date on which rain fell for any considerable part of the day; rain fell during a part of the afternoon of the 26th, on the early morning of the 25th, and during the night of the 28th to 29th. The total precipitation for the month was below the average, but the excess from September made the seasonal amount practically normal at the end of the month. The most intense rain occurred in the early morning of the 25th, when 7.4 millimeters, 0.29 inch, fell in about two hours; no rates can be given, as recording gage records are not available.

November temperatures were not far from the average for the month. The mean for the month under the old conditions of exposure was 285.1° A, 53.7° F. The results of the change of thermometer exposure were maxima averaging 2.6° A, 4.6° F, higher, and minima averaging 0.4° A, 0.7° F, lower in the standard than in the window shelter. The early part of the month was generally cloudy, with small temperature ranges; it was then that the rain occurred. The latter part of the month was a time of generally clear weather with mild days and cool nights. Frost occurred during this period.

The rainfall for the month was about 50 per cent in excess of the average. It was the result of three storms. The first lasted from the 3rd to the 10th, resulting in precipitation which amounted to 90.2 millimeters, 3.55 inches, in all. Although there were two periods of precipitation, one on the 5th and 6th, and the other on the 9th and 10th, the pressure conditions remained about the same during the whole period. The second storm, with a rainfall of 1.3 millimeters, 0.05 inch, and the third, with a rainfall of 7.4 millimeters, 0.29 inch, occurred between the 12th and the 20th.

Except for a north wind with a velocity of about 12 meters a second (25 miles an hour) or more on the 20th and early morning of the 21st, the winds were mostly light airs from the south and west. Cool northwest winds of low velocity were recorded occasionally during the month. Fog, dense enough to obscure nearby objects, was observed on the morning of the 13th and on the evening of the 28th. In the three other cases of fog the mist was very light.

December, 1912—The temperature conditions of this month were not far from the average. The mean temperature under the old conditions of exposure was 0.8° A, 1.4° F, lower than the mean from the standard shelter; the mean maximum was 1.9° A, 3.5° F, lower, and the mean minimum was 0.3° A, 0.6° F, higher in the window shelter. The departures from the daily normals were in most cases slight. The general impression that the month was clear and cool was due to the very considerable amount of north and northwest wind.

Frost was observed on the Campus on thirteen mornings, between the 1st and the 9th and between the 20th and the 28th. Heavy frost was recorded on the 24th and the 27th. Because of the diversified topography of Berkeley no general statement as to the occurrence of frost is

possible. The available frost records seem to indicate that frost occurred more often in December, 1912, than in the average December. The mean conditions of sunshine and cloudiness for the month were about the average, although the amount of precipitation was less than half the average for December. The amount of precipitation was less than that for December in twenty-two of the twenty-five other years of the record. The seasonal deficiency to the end of the month was not great because of the excess at the beginning of the month. The lower records of humidity and dew-point were in part due to the change in the exposure of the thermometers.

The wind for the month was generally light; moderate to high winds occurred on the 5th, 6th, and 21st, all from a northerly direction. The prevailing winds were southerly and southwesterly, but there was a considerable amount of cool northerly wind.

JANUARY, 1913, was the coldest January since the establishment of this station, with the exception of January, 1888. The number of days with frosts has been exceeded five times, but the mean for the month under similar conditions of exposure was lower than that for any January except 1888 and 1910. The minimum temperature, 270.6° A, 27.7° F, on the 6th, is lower than any except those of January 14, 15, and 16, 1888.

A period of heavy frosts occurred at the beginning of the month and another from the 19th to the 24th.

Snow fell for about three hours during the forenoon of the 9th, but generally melted as it reached the ground; in places the ground was white at times and the hills remained white throughout the day. Thunder and lightning occurred between midnight of the 14th and 1 a.m. of the 15th in the middle of a rain period which lasted about a week. The rainfall to the end of the month was 79.8 millimeters, 3.14 inches, below the normal seasonal amount.

The sky was somewhat less cloudy than the normal, which is in part responsible for the low temperatures of the month. Unusually dense fog occurred on the mornings of the 28th, 29th, and 30th.

The wind at the observation hours was prevailingly from the south and was in general light through the month. A strong south wind blew during the early morning hours of the 15th.

FEBRUARY, 1913—The temperature of this month was probably slightly below the normal, although the mean was 0.5° A, 0.9° F, above the average of the twenty-six years; but this is probably due to the change in exposure, as the former conditions give means below the average. Heavy frosts were recorded on the Campus on the 22nd and the 28th.

There was somewhat more fog than the average for the month; dense fog occurred on the mornings of the 10th, 12th, 13th, and 14th, and the evening of the 10th, and light fog on the 9th and 11th. The fog cleared on the Campus in all cases by noon. The sky was overcast on fourteen mornings, which made the average morning cloudiness high, but the sky was overcast on only five evenings during the month.

The precipitation was nearly 36 per cent below the average to the end of February, and about 80 per cent below the average for the month. In only four years since the establishment of the station in 1886 has there been as small a rainfall for February—1889, 13.7 millimeters, 0.54 inch; 1896, 9.1 millimeters, 0.36 inch; 1899, 5.6 millimeters, 0.22 inch; and 1912, 13.7 millimeters, 0.54 inch. The number of days with precipitation (eight) is somewhat misleading, as on three of these days the precipitation was from fog and amounted to only 0.2 millimeter, 0.01 inch, in each case.

The wind was mainly westerly—nine days from the west, five from the northwest, and four from the southwest. The observation hours frequently do not show the prevailing wind for the day. High northeast wind was recorded during the morning of the 1st and again on the night of the 1st to 2nd. At all other times during the month the velocity was light or moderate, with a great deal of calm, but there was no whole day without wind.

March, 1913, was a month of generally clear skies, which caused large ranges of temperature. The mean daily range was about 30 per cent above the average for the twenty-six years of record, but this increase in range is in part due to the change in the exposure of the thermometers, as the range in the window shelter averaged only 8.7° A, 15.7° F, which was 0.6° A, 1.1° F, less than the average. The mean temperature for the month from the window shelter was 1.0° A, 1.8° F, lower than that from the standard shelter; the mean maximum was 2.3° A, 4.1° F, lower, and the mean minimum was 0.4° A, 0.7° F, higher.

Heavy frosts occurred on the 15th and the 24th, and light frosts on three other days. This is probably more than is usual, but the local character of frosts and the differences between observers make comparisons difficult. The fog all occurred during the morning, dense fog on the 5th, 30th, and 31st. On the 5th and 30th the fog over the Campus was dense enough to obscure nearby objects, but of so little thickness upward that the sun shone brightly enough to cast a distinct shadow.

Only two storms occurred during the month, one on the 17th and 18th and the other from the 21st to the 23rd. Probably both were parts of the same general storm.

The wind was prevailingly from the west and southwest during the day; the large number of south winds is due to temporary conditions at the observation hours. The velocity was generally not over five meters a second, ten miles an hour.

April, 1913, was a month of considerable sunshine, although half the days were recorded as partly cloudy. The sky was overcast at fourteen morning and twelve evening observations. During the daytime hours the sky was generally clear. The clear days in part explain the excess of 1.8° A, 3.2° F, in the mean maximum temperature, and the occurrence, on the 24th, of a temperature of 303.3° A, 86.6° F, which is the highest April temperature since the establishment of the station; but on that date under the old conditions of exposure the maximum was 300.8° A,

82.0° F, which had been exceeded in four earlier Aprils. The mean monthly temperature under the old conditions of exposure was 1.1° A, 2.0° F, lower than the mean from the standard shelter.

The seasonal amount of precipitation, while 258.5 millimeters, 10.18 inches, below the average to the end of April, was 58.7 millimeters, 2.31 inches, more than the seasonal amount to the end of April, 1912. There was no fall of rain of any consequence during April, 1913.

MAY, 1913, was a mild month, both high and low temperatures being rare. The main departure of the mean conditions from the average was the 8 P.M. mean temperature which was 1.3° A, 2.3° F, lower than the twenty-one year average. This was due to the change in exposure; the mean at 8 P.M. under the old conditions was 0.5° A, 0.9° F, higher than the average. The mean temperature from the window shelter was 0.1° A, 0.2° F, lower than that from the standard shelter.

Cloudiness was slightly higher than the normal at the observation hours and the record shows fewer clear days; but the records of both depend upon the judgment of the individual observers, and the results for different years cannot be regarded as strictly comparable. Fog, as defined by the international usage, was not recorded during the month, as there was no time at which the Campus was in fog. Low stratus cloud, locally known as "fog," obscured the hills on four days.

The seasonal precipitation to June 1, 1913, was 397.2 millimeters, 15.63 inches. The amount for May, 1912, was 39.6 millimeters, 1.56 inches, and the seasonal amount to June 1, 1912, was 352.6 millimeters, 13.88 inches. The seasonal amounts for the two other very dry years were 359.7 millimeters, 14.16 inches, to June 1, 1898, and 431.6 millimeters, 16.99 inches, to June 1, 1888.

The wind was generally very light at the observation hours, but during the day the moderate southwest breeze, characteristic of the summer months in this region, was common. The general wind direction was southwest on fifteen days, west on eight days, and south on four days. Two days were recorded as practically without wind.

JUNE, 1913, was characterized by mild temperatures, no marked extremes being observed. This was the first month of the season in which the mean maximum was higher from the thermometer in the window shelter than from that in the standard shelter. Higher maxima were observed in the window shelter on the days when the air movement was light; there was considerable wind movement and higher temperatures were observed in the standard shelter.

Cloudiness during the month was not far from normal. The higher morning cloudiness was due to the number of mornings on which the sky was covered with the so-called "high fog." True fog was observed on the Campus on the evening of the 22nd; on the 24th the cloud was very low on the hills and probably appeared as fog in the higher parts of Berkeley.

Except for a trace of rain on the morning of the 22nd, no precipitation was recorded, although a few drops of rain fell on the evening of the 26th and perhaps on other evenings of the same week. The amount of precipitation for the season 1912–13 was 397.2 millimeters, 15.63 inches, which is 60 per cent of the seasonal normal. In the twenty-six years of the record there have been but two seasons, 1897–98 and 1911–12, with a smaller amount of precipitation than 1912–13; these are the only seasons in which the amount was less than 400 millimeters, 16 inches.

The wind was generally light and prevailingly from the southwest. The general direction on seventeen days was southwest; on seven, west; and on four, south. The velocity was usually low, 5 to 7 meters a second, 10 to 15 miles an hour, or less; but on the afternoon of the 25th a velocity of perhaps 12 meters a second, 25 miles an hour, was observed.

ATMOSPHERIC PRESSURE

Atmospheric pressure has been measured twice daily by a Fortin cistern, mercurial barometer of the United States Weather Bureau type. The mean pressure for each month has been computed and the mean for the year from the twelve monthly means. These are simply the means of the observed pressures; no attempt has been made to reduce the pressure observations to a twenty-four hour mean, or to calculate hourly variations, or to determine the amplitude of the diurnal wave, which is generally clearly marked on the barograph trace. Because of the relative unimportance of pressure as a climatic element, few pressure data have been included in Table I, the summary of the meteorological conditions for each month and for the year. Sea-level equivalents have been used in all cases, because the surface of Berkeley is so uneven that station pressures have only an extremely local significance and because a common basis is necessary for comparison with other stations, for which basis sea-level is usually employed. The station pressures are in practically all cases 12 millibars (8.9 millimeters or 0.35 inches of mercury, under standard conditions)[5] lower than the sea-level equivalents at the same time, the constancy of the air temperature being such that the reduction to sea-level is nearly always the same amount.

[5] For definitions of the C.G.S. meteorological units see footnote 2, on page 254. Conversion tables may be found in the Observer's Handbook of the (British) Meteorological Office, 1910, London, 1911.

The mean of the monthly pressures for the year was 1.018 bars in the rational units of megadynes per square centimeter (763.8 millimeters or 30.07 inches of mercury). The highest monthly mean was that for December, 1.024 bars (768.1 millimeters or 30.23 inches), and the lowest monthly mean was that for September, 1.015 bars (761.0 millimeters or 29.96 inches). That the pressure conditions exert an important control over the movements of cyclones and anticyclones with the resulting effect on temperature and precipitation for the Pacific Coast region has been shown by McAdie.[6] How far the pressure conditions at Berkeley represent the extensions of the continental and oceanic high or low pressure areas (the centers of action of Teisserenc de Bort, or hyperbars and infrabars of McAdie) offers an interesting field for study, but one which as yet has not been worked out for this station, although McAdie's work on the general distribution of seasonal pressures on the Pacific Coast and their influence on the storm tracks and other meterological conditions of the region should be mentioned.

Besides the mean pressures for the months of the year, the maximum and minimum pressures for each month have been determined from the corrected barograph trace. These maxima and minima are given in Table I. From these data some idea of the pressure variations, particularly those due to cyclones and anticyclones, may be obtained; although a better record of the pressure variations may be obtained from a study of the barograph trace itself. The extreme variation in atmospheric pressure was 34 millibars (2.56 millimeters or 1.01 inches). The maximum pressure for the year occurred on January 7 at the time of the minimum temperature, so that the evidence at Berkeley does not show whether the temperature or the pressure was the controlling factor; the maximum pressure for the year was 1.036 bars (776.7 millimeters or 30.58 inches). The minimum pressure, 1.001 bars (751.1 millimeters or 29.57 inches), occurred on February 25, and was, therefore, of cyclonic origin.

[6] McAdie, A. G., Forecasts on the Pacific Coast, Mo. Wea. Rev., vol. 36, pp. 98–100, Washington, 1908; Improving the Forecasts, Bull. Mt. Wea. Obs., vol. 3, pp. 235–238, Washington, 1910; Forecasting the Water Supply in California, Mo. Wea. Rev., vol. 41, pp. 1092–1093, Washington, 1913.

TEMPERATURE

Temperature data for Berkeley for the year are somewhat fully summarized in Table I. The mean air temperatures for each month of the twenty-six years of the record, for the seasonal years, ending June 30, and for the calendar years, together with the averages for the same period, are given in Table II on page 273 in absolute degrees, and in Table II*a* on page 274 in Fahrenheit degrees. In compiling Table II it appeared that there were small differences in the mean temperatures obtained through different channels, although the original observation data were all the same; in most cases these differences were less than a quarter of a degree Absolute (half a degree Fahrenheit). Wherever possible the published figures of the United States Weather Bureau have been followed, as in these cases the computations have been carefully checked by the Weather Bureau and the possibility of arithmetical error reduced to a minimum. It is probable that the differences have no effect upon the averages for the months and little or no effect upon the seasonal and annual means.

It is not practicable at this time to attempt a comparison between the year ending June 30, 1913, and the preceding years, or even with the averages for the observation period, because of the change in the conditions of exposure. The standard shelter now in use shows generally higher maxima and lower minima than the window shelter. There is less difference in the mean daily temperatures, but these means are not the same from the two conditions of exposure. For the relations between the two exposures during the year see the extracts from the monthly reports on pages 264 to 270, during the past year these differences averaged 0.8° A, 1.5° F. The period of comparison is not regarded as long enough to establish a correct relation between the two conditions of exposure. In general the means from the window shelter were lower in 1912–13 than the means from the standard shelter.

Curves of the annual march of mean monthly temperatures, of mean monthly maxima, and of mean monthly minima have been plotted in figure 3. These curves and the appropriate

TABLE II.—MONTHLY, SEASONAL, AND ANNUAL MEAN TEMPERATURES AND AVERAGES FOR BERKELEY, CALIFORNIA, 1887–1913 IN ABSOLUTE DEGREES

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal	Year	Annual
1887–88	290.5	288.1	290.7	290.7	285.4	282.8	279.9	283.9	283.4	285.9	286.8	290.2	286.6	....	....
1888–89	289.1	289.9	290.7	289.3	286.2	283.7	281.8	283.7	286.1	286.9	287.6	289.2	287.0	1888	286.8
1889–90	289.1	289.5	289.7	288.6	286.6	282.2	279.6	282.0	284.4	285.6	288.1	289.6	286.2	1889	286.7
1890–91	289.3	291.2	291.2	289.7	287.6	282.9	283.9	282.9	284.9	285.1	287.1	290.3	287.2	1890	286.8
1891–92	291.0	291.4	290.4	288.4	288.0	282.7	283.3	284.8	284.7	284.8	287.8	288.3	287.1	1891	287.2
1892–93	289.1	290.9	289.3	288.2	286.0	282.9	281.2	282.1	283.3	284.2	287.4	289.1	286.1	1892	286.7
1893–94	290.1	288.9	288.7	287.1	285.4	283.3	280.8	281.1	282.9	286.1	286.9	288.2	285.8	1893	285.9
1894–95	289.1	290.3	291.0	288.1	287.1	281.9	281.1	284.3	283.8	285.8	288.6	289.8	286.7	1894	286.1
1895–96	290.1	289.8	289.4	288.1	285.7	281.2	283.4	284.9	285.0	287.2	287.3	289.7	286.8	1895	286.5
1896–97	291.0	290.8	289.2	288.3	283.7	283.4	280.8	282.3	281.7	287.3	288.6	290.2	286.4	1896	287.0
1897–98	290.4	289.3	290.0	286.4	283.6	282.0	280.1	282.8	283.4	286.5	285.9	290.3	285.9	1897	286.0
1898–99	289.4	289.5	289.2	288.9	285.1	282.0	283.0	283.4	248.1	286.0	286.0	289.2	286.3	1898	286.1
1899–1900	288.7	289.2	289.1	287.7	285.9	282.1	284.0	283.9	285.7	285.3	288.8	289.7	286.7	1899	286.2
1900–01	290.3	290.0	290.7	288.1	286.2	282.8	282.3	283.7	286.0	284.8	286.8	289.3	286.7	1900	287.1
1901–02	289.0	289.0	288.7	289.9	286.8	283.3	280.6	284.2	283.2	285.6	286.9	289.4	286.4	1901	286.6
1902–03	290.2	290.4	290.6	288.0	284.2	282.0	281.0	280.8	283.4	284.9	287.2	290.2	286.1	1902	286.3
1903–04	289.1	288.9	289.2	288.6	285.1	282.4	281.3	281.6	283.0	286.1	288.6	289.5	286.1	1903	285.9
1904–05	288.3	288.0	290.4	287.8	285.1	281.0	282.3	283.3	285.4	285.8	286.1	287.7	285.9	1904	285.9
1905–06	289.3	288.4	288.8	287.4	284.6	281.6	282.0	285.7	285.0	286.6	287.2	289.9	286.4	1905	285.9
1906–07	290.4	289.4	290.1	289.3	285.3	282.3	281.1	285.6	283.2	287.1	287.7	288.9	286.7	1906	286.9
1907–08	289.8	289.9	289.2	288.8	285.8	283.3	....	....	284.6	286.9	287.2	288.4	BR	1907	286.7
1908–09	289.9	289.1	289.6	287.7	284.7	280.6	283.2	282.8	283.3	286.9	287.0	288.8	286.1	1908	BR
1909–10	290.1	289.3	290.2	287.8	284.5	281.7	279.8	281.8	285.1	286.9	289.0	288.4	286.2	1909	286.3
1910–11	288.9	287.9	287.6	288.3	284.3	283.2	282.3	280.9	284.9	285.3	287.0	287.8	285.7	1910	285.9
1911–12	288.3	288.0	288.0	288.1	285.2	282.0	282.9	284.0	283.4	284.7	288.0	289.9	286.0	1911	285.6
1912–13	289.4	290.2	291.5	288.6	286.1	283.1	280.9	283.2	284.2	285.8	287.4	289.3	286.4	....	286.4
Averages	289.6	289.5	289.7	288.4	285.6	283.4	281.7	283.8	284.0	286.3	287.7	289.1	286.7	1912	286.8

NOTE.—A change in the conditions of thermometer exposure April 1, 1912, makes the means before not strictly comparable with those after that date. Minimum temperatures for January and February, 1908, are not available.

Table IIa.—Monthly, Seasonal, and Annual Mean Temperatures and Averages for Berkeley, California, 1887–1913, in Fahrenheit Degrees

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal	Year	Annual
1887–88	63.5	59.2	63.9	63.8	54.4	49.6	44.4	51.6	50.8	55.2	56.8	63.0	56.4	....	......
1888–89	61.2	62.4	63.9	61.2	55.8	51.2	47.8	51.2	55.5	57.1	58.2	61.1	57.2	1888	56.5
1889–90	61.0	61.7	62.0	60.1	56.4	48.5	43.8	48.2	52.6	54.6	59.2	61.8	55.8	1889	56.7
1890–91	61.4	64.8	64.8	62.0	58.2	49.8	51.7	49.8	53.4	53.8	57.4	63.2	57.5	1890	56.8
1891–92	64.4	65.2	63.4	59.8	59.0	49.4	50.6	53.3	53.0	53.2	58.6	59.6	57.5	1891	57.5
1892–93	61.0	64.2	61.4	59.3	55.4	49.8	46.8	48.4	50.6	52.1	58.0	61.0	55.7	1892	56.5
1893–94	61.8	60.6	60.2	57.4	54.3	50.6	46.0	46.6	49.8	55.6	57.0	59.4	54.9	1893	55.2
1894–95	60.9	63.0	64.4	59.1	57.4	48.0	46.6	52.3	51.5	55.0	60.0	62.3	56.7	1894	55.6
1895–96	62.8	62.2	61.5	59.2	54.8	46.8	50.8	53.4	53.6	57.6	57.7	62.0	56.9	1895	56.2
1896–97	64.4	64.1	61.2	59.5	51.2	50.8	46.1	48.7	47.7	57.7	60.0	63.0	56.2	1896	57.0
1897–98	63.3	61.1	62.6	56.2	51.0	48.2	44.8	49.7	50.8	56.3	55.2	63.1	55.2	1897	55.5
1898–99	61.6	61.7	61.2	60.6	53.7	48.2	50.0	50.8	52.0	55.4	55.4	61.2	56.0	1898	55.6
1899–1900	60.2	61.2	60.9	58.4	55.2	48.3	51.8	51.6	54.8	54.2	60.4	62.1	56.6	1899	55.8
1900–01	63.2	62.6	63.8	59.1	55.8	49.7	48.8	51.2	55.4	53.2	56.8	61.1	56.7	1900	57.4
1901–02	60.8	60.8	60.2	62.4	56.8	50.5	45.6	52.1	50.4	54.7	57.0	61.6	56.1	1901	56.5
1902–03	63.0	63.3	63.6	59.0	52.1	48.2	46.4	46.1	50.8	53.4	57.6	62.9	55.5	1902	55.9
1903–04	61.0	60.7	61.2	60.0	53.8	49.0	46.9	47.4	50.0	55.4	60.0	61.7	55.6	1903	55.2
1904–05	59.6	59.0	63.4	58.6	53.8	46.4	48.7	50.6	54.3	55.1	55.6	58.4	55.3	1904	55.2
1905–06	61.4	59.8	60.4	58.0	52.9	47.4	48.2	54.8	53.6	56.8	57.6	62.4	56.1	1905	55.2
1906–07	63.4	61.6	62.8	61.3	54.2	48.7	46.6	54.7	50.4	57.4	58.5	60.6	56.7	1906	57.1
1907–08	62.2	62.4	61.2	60.4	55.0	50.6	......	......	52.8	57.0	57.5	59.7	BR	1907	56.7
1908–09	62.5	61.0	61.8	58.4	53.0	45.6	50.4	49.6	50.5	57.0	57.2	60.4	55.6	1908	BR
1909–10	62.8	61.4	62.9	58.6	52.7	47.6	44.2	47.9	53.8	57.0	60.8	59.8	55.8	1909	55.9
1910–11	60.6	58.9	58.3	59.6	52.4	50.4	48.8	46.2	53.4	54.2	57.2	58.6	54.9	1910	55.3
1911–12	59.6	59.0	59.0	59.1	54.0	48.2	49.8	51.8	50.8	53.0	59.0	62.5	55.5	1911	54.8
1912–13	61.5	63.0	65.3	60.0	55.6	50.2	46.2	51.4	51.8	56.0	58.4	61.0	56.7	1912	56.9
Averages	61.9	61.7	62.1	59.7	54.6	50.8	47.7	50.4	52.1	55.1	58.0	61.3	56.1	....	56.1

Note.—A change in the conditions of thermometer exposure April 1, 1912, makes the means before not strictly comparable with those after that date. Minimum temperatures for January and February, 1908, are not available.

figures in the two tables show the relative temperature conditions for each of the twelve months. The warmest month during the year was September, which is normally the warmest month in Berkeley. In this month the summer fogs and velo cloud sheet, "high fog," are not as common features as they are in July and August, so that the sun heating has more opportunity to make itself felt than in midsummer. The maximum temperature for the year, 311.2° A, 100.8° F, occurred on September 18, at a time when the hot, dry northeast wind was blowing. This wind is accompanied by high temperatures and low relative humidities at Berkeley, and hence clear skies, so that insolation is very effective. In addition to this, and the imported warmth, which may be brought with the wind from the Great Valley, the air is

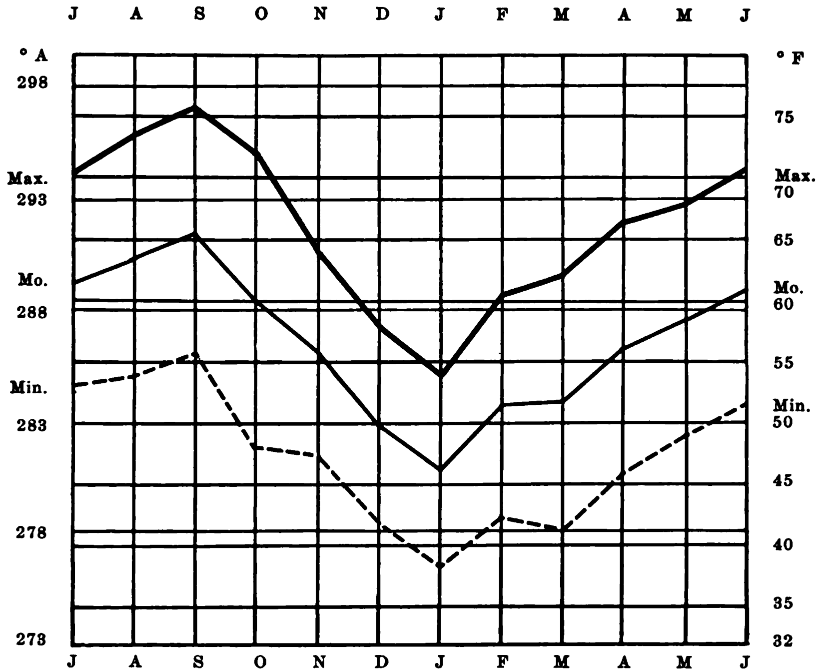

Fig. 3.—Annual march of temperature at Berkeley, California, 1912-13. Max, mean monthly maximum temperatures. Min, mean monthly minimum temperatures. Mo, monthly mean temperatures, ½ (maximum + minimum).

heated by compression and is, in part at least, a foehn. The temperature reached on September 18 was the maximum recorded in Berkeley in any September and one of the highest temperatures reached in any month. This comparison with other years is, however, not wholly fair because of the change in exposure; on the same date the maximum recorded in the window shelter was 307.4° A, 94.0° F, which was exceeded on September 7 and 8, 1904.

Table I and figure 3 show the general monthly temperature conditions at Berkeley during the year. September with a mean of 291.5° A, 65.3° F, was the warmest month of the year, and January with a mean of 280.9° A, 46.2° F, was the coldest. The annual march of temperature was a regular rise to September, then a regular and somewhat rapid fall to January, a sharp rise to February, followed by almost no change to March, and a moderate rise from March to June. The position of the mean monthly temperatures midway between the monthly maxima and minima is the result of computing the mean daily and monthly temperatures from the maxima and minima. This method is, however, to be preferred to all others based on combinations of two daily observations, although not as accurate as means based on a considerably larger number of observations. The difference in temperature between September and January, that is, between the warmest and the coldest months, was 10.6° A, 19.1° F. The relatively small amount of this annual periodic range and the times of occurrence of the warmest and the coldest months are the most characteristic features of the annual march of mean monthly temperatures at Berkeley for the year. Another feature of figure 3 worthy of note is the parallelism existing between the three curves, which indicates regularity of conditions throughout the year.

The mean monthly maximum temperatures[7] for 1912–13 were somewhat higher than the averages for the observation period; in a general way, however, the curves are parallel, which probably means that the differences are due rather to the change in

[7] Maximum and minimum temperatures are all from U. S. Weather Bureau pattern self-registering glass thermometers, not from the thermograph trace.

exposure than to a real temperature difference. The most marked departure from parallelism occurred in September, when the mean maximum for 1912–13 was more than three degrees Absolute, five degrees Fahrenheit, higher than the average September maximum. The mean maximum for January, 1913, was 285.2° A, 54.0° F, which is only 0.4° A, 0.7° F, higher than the average for January, but there is little doubt that January of this year was unusually cold.

In 1912–13 the march of mean monthly minimum temperatures shows the same characteristics as that of the mean monthly maxima and the mean monthly, except, of course, that it is lower in the temperature scale, but it is slightly less regular. The highest monthly minimum was in September and the lowest in January. The absolute minimum for the year, 270.6° A, 27.7° F, occurred on the morning of January 6, and a minimum below freezing occurred on the 7th.[8] The minimum for the year is one of the lowest temperatures of the record. The duration of the cold was sufficient to bring the minimum in the less free exposure of the window shelter to 270.8° A, 28.0° F, on January 7. Low temperatures were recorded on other dates in January.

Unfortunately no accurate observations of frost or of the occurrence of freezing temperatures near the surface of the ground have been made at Berkeley. The thermometers in the shelters are, of course, too far above the ground to reach freezing temperatures in most of the cases of frost occurrence. Besides this, the location of the shelter is such that there is a good system of air drainage, which tends to keep the temperature of the air in the vicinity higher than the minimum on the Campus; there will be a tendency for the chilled air to flow into the valley on nights with strong terrestrial radiation and the colder air will be replaced in the region of the Observatory by the warmer air from above the ground. Freezing temperatures are, therefore, not reached in the shelter under conditions which result in a moderately heavy frost in Berkeley. The diversified topography and the local nature of frost make the observation of this phenomenon rather uncertain. The number of days on which frost

[8] Considerably lower temperatures probably occurred on the Campus; see pages 256 and 257.

was observed are stated in Table I; it should be noted that this is rather the minimum number of days on which frost occurred during the year than the actual number of occurrences. In a general way, the statement of days with frost is of value as showing, what is certainly the case, that more than half the occurrences of frost were in the months of December and January. The first frost occurred about the middle of November and the last toward the end of March.

In Table III the highest and lowest temperatures recorded for each month during the period of the observations and the dates on which these temperatures occurred are shown. It may be noted that the highest maximum occurred not in September,

TABLE III.—EXTREME TEMPERATURE., JULY 1, 1887, TO JUNE 30, 1913

	Maximum			Minimum		
Month	° A	° F	Date	° A	° F	Date
July	309.3	97.3	7, 1905	278.7	42.3	29, 1899
August	307.1	93.4	22, 1891	281.0	46.4	31, 1905
September	311.2	100.8	18, 1912	280.7	45.9	28, 1905
October	307.4	94.0	8, 1899	277.1	39.3	18, 1905
November	300.8	82.0	16, 1895	273.6	33.0	28, 1905
December	293.9	69.6	24, 1901	272.4	31.0	24, 1905
January	298.0	77.0	26, 1899	269.1	24.9	14, 1888
February	299.4	79.5	18, 1899	271.4	29.2	12, 1905
March	298.8	78.5	29, 1911	274.1	33.9	30, 1905
April	303.3	86.6	24, 1913	275.2	36.0	19, 1896
May	306.6	92.5	26, 1896	277.4	39.9	1, 1899
June	311.4	101.1	6, 1903	278.8	42.4	2, 1903
Year	311.4	101.1	June 6, 1903	269.1	24.9	Jan. 14, 1888

NOTE.—Minimum temperatures for January and February, 1908, are not available.

the warmest month, but in June. January is the month in which the lowest minimum has been recorded, but December is the only month in which a maximum of 294° A, 70° F, has not been recorded.

The highest and lowest daily temperatures for each month have been recorded in Table I. In nine months of the past year the highest daily temperature occurred on the same day as the maximum temperature for the month and in one other case the highest daily temperature occurred on the day following the maximum. The relation between the lowest daily temperature and the minimum for the month does not seem to be as close; the lowest daily temperature occurred on the same day as the

minimum for the month in four months of the year, on the day following in two months and on the day preceding in one month. The temperature of the warmest day of the year, September 18, was 301.6° A, 83.5° F, and that of the coldest day, January 5, was 275.3° A, 36.2° F; there was a difference in temperature between the extreme daily means of 26.3° A, 47.3° F, in a period of three and a half months. The mean of the changes of mean temperature from day to day during the year was 1.4° A, 2.6° F; the greatest mean change for any month was 2.7° A, 4.9° F, in September, and the smallest 0.9° A, 1.6° F, in June. The changes from day to day in Berkeley are apparently due to differences in local heating and cooling, which displace the maximum or minimum temperature, and hence the mean of a single day, rather than to seasonal changes or cyclonic influence. It is, of course, true that cyclonic and anticyclonic conditions are for the most part indirectly responsible for the differences in the daily means, as the cloudiness conditions have an important effect upon the local heating and cooling, and cloudiness is to a considerable extent under cyclonic control. The cyclonic temperature conditions of Berkeley are little known and the whole question of cyclonic influence of weather in the region should be investigated.

RANGES OF TEMPERATURE

The daily ranges of temperature at Berkeley are for the most part moderate. The mean daily range for the past year was 10.6° A, 19.0° F. The mean daily range of temperature was the largest in October, 13.2° A, 23.7° F, and the smallest in January, 8.9° A, 16.0° F. The maximum daily range for the year was 20.2° A, 36.3° F, on October 13, when no cyclonic influence appeared on the barograph trace or on the weather map, and the smallest was 2.4° A, 4.4° F, on January 13, soon after the beginning of the passage of a well-defined cyclone (see Table VI on page 293). No attempt has yet been made to determine the periodic daily ranges, that is, the difference between the temperature of the warmest hour and that of the coldest hour. All the ranges in Table I are non-periodic; that is, they are the differences between the maximum and minimum at whatever time they occurred.

The mean monthly range of temperature, 21.4° A, 38.5° F, was about twice the mean daily range. Monthly ranges are the differences between the maximum and the minimum temperature for the month. The greatest monthly range was 29.2° A, 52.6° F, in September, and the smallest was 15.5° A, 27.9° F, in December. What relation there may be between the ranges for the day and for the month do not show very clearly. The monthly range must be greater than the greatest daily, because it is very unusual for the highest and the lowest temperature of the month to occur on the same day.

The periodic annual range, or the annual mean range, of temperature, which is the difference in mean temperature between the warmest and the coldest month, September and January respectively, was 10.6° A, 19.1° F, which is almost exactly the same as the mean daily range for the year. While this close correspondence is probably merely a coincidence, the fact that the daily and annual ranges are approximately the same is the result of the "meteorological latitude" of Berkeley, between the tropical zone, where the dominant emphasis is on the daily rather than the annual range, and the intermediate zone, where the emphasis is on the annual rather than the daily range. The annual extreme range for the year was 40.6° A, 73.1° F; this is the difference between the maximum and the minimum temperatures of the year.

All the ranges are larger than the averages for the observation period because of the freer exposure of the thermometers in the standard shelter than in the window shelter, which results in generally higher maxima and lower minima, with consequently greater ranges. None of the ranges for Berkeley can be regarded as extreme when compared with the ranges for other stations. The moderate character of the temperature regime is as well shown by the ranges as by any other temperature condition.

ATMOSPHERIC MOISTURE

The amount of water vapor in the atmosphere at Berkeley has been determined by the use of the wet and dry bulb thermometers, exposed in the instrument shelters. There is a good deal of doubt whether the results represent the actual condition

of the air, as the ventilation of the wet bulb is probably inadequate. Because of lack of room in the shelter it has been necessary to use fixed wet and dry bulb thermometers instead of a whirling apparatus. The lack of perfect ventilation results in temperatures of evaporation which are somewhat too high, but the amount of error has not been determined. It is probable that the temperatures of the dew-point, the relative humidities and vapor pressures, are all somewhat too high. The figures as computed from the readings of the thermometers are recorded in Table I for what they may be worth, the amount of error is in most cases probably not great. The highest humidities occur in the summer months when fog is more usual; the higher dew-points and vapor pressures occur at the same season because of the greater amount of water vapor and the greater capacity of the warmer air for water vapor.

The range of the mean dew-points is about that of the monthly mean temperatures. The highest mean dew-point was 286° A, 56° F. in September, and the lowest was 275° A, 36° F, in January, which shows the close relation between the dew-point and the air temperature. The mean vapor pressure was at all times small, the highest temperatures occurring with low relative humidities. In no month was the mean vapor pressure as high as 20 millibars (12.7 millimeters or 0.50 inch of mercury), which is about one-sixtieth of the total pressure at Berkeley, and in most cases the portion of the total height of the barometric column supported by the pressure of aqueous vapor was much less than this fraction. The amount of water vapor is one of the factors controlling the "sensible (subjective) temperature," and the fact that the warmest days are accompanied by small amounts of vapor tends to make these days less oppressive and to facilitate the rapid cooling after the sun's heating ceases to be effective. The mean relative humidities, as shown by Table I, indicate that, subject to the errors due to the conditions of exposure, the air over Berkeley was somewhat more than three-quarters saturated, on the average, during the past year. Maximum humidities of 100 per cent have been observed in fogs and a minimum of about 15 per cent was recorded with the high temperature and foehn conditions on September 18; this minimum reading may be lower

than the actual relative humidity at the time, but it is true that the air was very dry for a few hours on that date.

The mean cloudiness at the observation hours, which is the only time for which records are available, was somewhat greater in summer than in winter. In summer the "high fog," a low stratus cloud, is not an uncommon phenomenon in the morning and the evening. This is the only common summer cloud and, in a general way, it may be stated that mean cloudiness of a summer month represents roughly the occurrence of fog or "high fog" at the times of observation. This is not the case in the winter months, when the clouds over Berkeley are largely of cyclonic origin. In the winter months cloudiness is more or less related to rainfall, as both are the result of the passage of cyclones near enough to affect the weather of Berkeley; but there are cyclones, whose passage is shown by the barograph trace and the weather maps, the effect of which on the weather of Berkeley is limited to an increase in cloudiness.

WEATHER

The weather, state of the sky is, of course, closely related to the cloudiness and the humidity. In Table I the number of days which were generally clear, generally partly cloudy, and generally cloudy are recorded for each month, and the total of each class for the year. These include all the days of the year, as the cloudiness has been recorded regardless of other phenomena such as rain; fog has been regarded as cloud. Days on which the cloudiness was less than three-tenths during the day, or on which the sky was cloudy for less than three-tenths of the time, have been entered as clear; obviously such days have been characterized by sunshine during the daytime hours and by starlight or moonlight at night. These days have been non-foggy in summer and non-stormy in winter. They were the days of largest temperature range. The total number of clear days, 159 for the year, was not quite half the days of the year. The smallest number of clear days in a single month was five in July; this month was the only one in which fewer than one-third of the days were clear. The largest number of clear days in a single month was nineteen in October.

The partly cloudy days fall into two classes, those on which the sky was more than three but less than seven-tenths cloudy throughout the day, and those on which the sky was overcast or nearly so for a part of the day and clear for a part of the day; in either case the average amount of cloud for the day was between three-tenths and seven-tenths. The type of day on which the sky was partly cloudy throughout the day is more usual in the winter than in the summer months; it is generally associated with the margin of a cyclone, and may occur at the beginning or toward the end of a passage with the center near the station, or during the passage of a cyclone with the center at some distance from the station. The other type of partly cloudy day is probably the more common at Berkeley. In summer this type occurs with fog or "high fog" in the morning or evening hours, or both, while the greater part of the daytime hours are clear. In winter there is a similar condition when "tule fogs" have drifted southward from the marshes of Suisun Bay and the Sacramento River. The two types of partly cloudy day are the cyclonic, which is the first-mentioned, and the non-cyclonic of the summer and the anticyclonic of the winter, which together constitute the second type mentioned.

There were eighty-four days, about a quarter of the total number, which were generally cloudy during the year. In general these days have been associated with cyclones, although in some cases, especially in summer, they are the result of the persistence of morning and evening cloud, or "high fog," through the day. The maximum number of cloudy days was eleven in January, and the minimum was one in October; for the cyclonic conditions in these two months see Table VI on page 293.

FOG

No tabular statement of fog can show the conditions at Berkeley as they exist. An attempt has been made to keep the recorded fog at the Berkeley station within the requirement of the International Meteorological Committee that "fog (mist) is to be recorded only when the observer is enveloped in it."[9] In a region of hills and valleys upon which there is fog (or air of

[9] Internationaler Meteorologischer Kodex (ed. 2, Berlin, 1911), p. 18.

high relative humidity from which fog has not yet been condensed), or over which there is drifting a cloud whose base is lower than the tops of the hills, it is obvious that the exact position of the observer is a controlling factor in determining whether fog is or is not to be recorded. In many cases fog has not been recorded because no fog was observed on the Campus, although in many parts of Berkeley fog actually existed. Perhaps the local term "high fog" is as expressive of the actual condition of affairs as is possible. The occurrences of "high fog" at the station for each month will be found in the extracts from the monthly reports on pages 264 to 270. "High fog" has been recorded only when the tops of the hills immediately east of the Campus have been covered with cloud; the altitude of these hills is about three hundred meters, one thousand feet, above sea-level and about two hundred meters, seven hundred feet, above the level of the Campus. In the more elevated parts of Berkeley fog occurred on more than the forty days on which it was observed on the Campus, and in the less elevated parts of the city, with the exception of the shore of San Francisco Bay, less often. The winter fogs were generally of the "tule fog" type from the marshes to the north, and the summer fogs were the California coast fogs brought in from the ocean by the westerly and southwesterly wind.

PRECIPITATION

The total precipitation of all kinds for the year 1912–13 was 397.2 millimeters, 15.63 inches. The monthly and yearly amount is shown in Table I. In addition to the data given in Table I, the monthly and seasonal rainfall of Berkeley from 1887 to 1913 has been compiled and is presented as Table IV on page 286 in metric units and as Table IVa on page 287 in English units.[10] In addition to these two tables, the monthly rainfall and the total from July 1 to the end of each month, with the departures from the average for the same period, have been compiled for Table V on page 288. The monthly amounts of precipitation for 1912–13 and the average monthly amounts are shown by figure 4.[10]

[10] Table IV*a* is extended from Table I of The Rainfall of Berkeley, California, Univ. Calif. Publ. Geog., vol. 1, no. 2, 1913. Figure 4 is figure 2 of the same paper, with the precipitation for the rainfall year 1912–13 added.

The rainfall year was one of marked shortage in precipitation, as may be seen from an examination of Table V. By itself the past year will stand out as one of the very dryest years of the record, but the condition of drought is especially noteworthy because the preceding season, that of 1911–12, was one of very little rainfall. Never since the establishment of the station have two such dry seasons occurred in succession, and consequently there is a marked shortage at the end of the season of 1912–13.

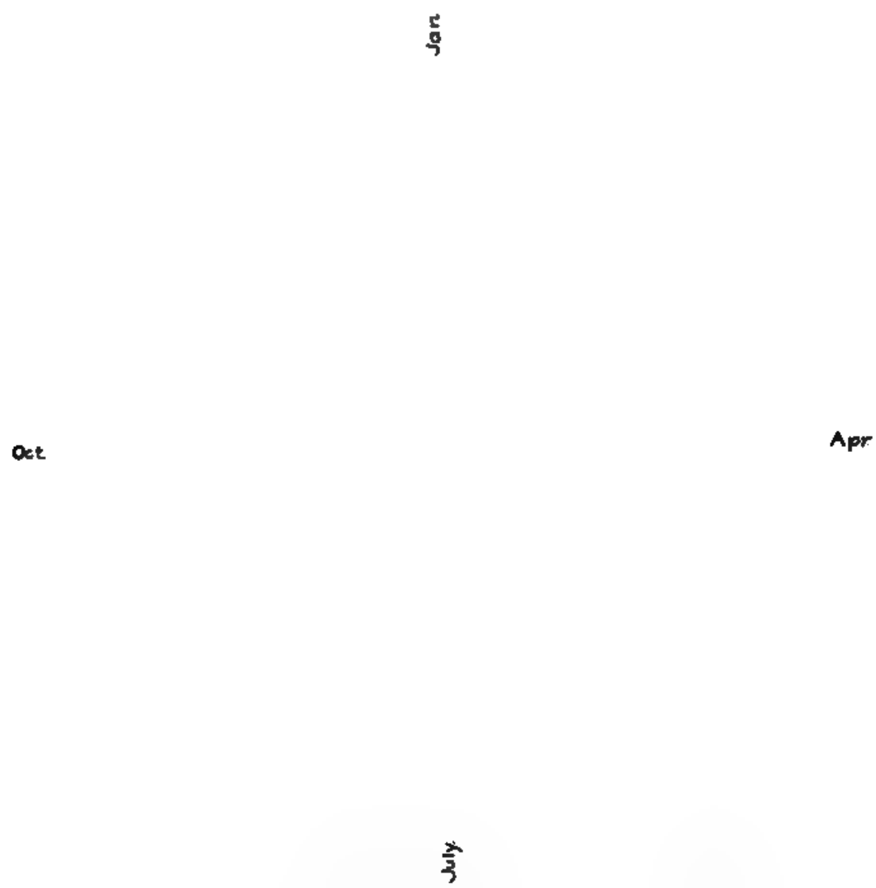

Fig. 4.—Average monthly precipitation at Berkeley, California (25 years), shaded, and monthly precipitation for the year ending June 30, 1913. Heavy circles indicate scale of millimeters. Light circles indicate scale of inches.

TABLE IV.—MONTHLY AND SEASONAL PRECIPITATION, 1887–1913, IN MILLIMETERS

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal
1887–88	0.2	.	10.2	.	19.0	74.7	148.3	48.8	114.3	5.1	10.7	12.7	444.0
1888–89	.	.	15.0	0.5	68.8	96.3	19.8	13.7	192.5	18.3	38.1	1.5	464.5
1889–90	.	.	.	147.3	60.7	319.8	283.5	144.8	120.1	55.4	36.6	.0.0	1168.2
1890–91	.	.0.0	6.4	.	.	84.3	28.7	271.3	80.5	86.9	40.9	9.6	608.6
1891–92	11.2	.	18.8	4.6	25.6	158.0	59.4	106.7	91.4	42.7	75.4	.	593.8
1892–93	0.2	.	1.8	50.6	135.9	168.7	99.1	83.3	157.2	40.9	6.6	.	744.3
1893–94	.	.	9.6	13.2	132.6	66.6	242.3	95.8	23.1	14.5	51.0	28.2	676.9
1894–95	.	.	40.9	83.6	34.3	320.8	276.4	82.6	67.1	58.4	26.9	.	991.0
1895–96	1.0	.	32.5	1.8	45.2	55.9	289.6	9.1	74.4	170.7	23.9	.	704.1
1896–97	.0.0	22.9	19.3	48.5	130.8	125.0	94.2	118.9	151.6	11.1	5.1	7.6	735.0
1897–98	.	.	5.1	63.0	40.1	68.8	39.1	83.3	7.9	4.8	47.5	6.1	365.7
1898–99	.	1.0	23.6	47.8	24.6	31.0	149.9	5.3	335.0	39.6	43.2	1.3	702.3
1899–1900	.	.0.0	.	133.6	148.5	87.6	106.2	25.9	76.2	40.1	23.1	2.0	643.2
1900–01	.	0.5	1.2	35.8	128.0	46.5	148.6	150.1	23.1	77.7	25.9	.	637.4
1901–02	.	.	33.0	17.2	80.3	37.6	34.5	265.9	105.9	39.4	42.9	.	656.7
1902–03	.	.0.0	.	59.7	81.5	93.7	131.3	51.8	198.4	28.2	0.5	.0.0	645.1
1903–04	.	.	.	12.7	149.6	55.6	35.6	265.4	280.4	53.3	0.5	.0.0	853.1
1904–05	.	1.8	112.8	86.1	56.6	51.8	141.7	65.0	108.0	34.8	87.1	.	745.7
1905–06	.	.	.	.	37.1	56.4	175.8	100.6	230.0	18.8	65.0	16.3	700.0
1906–07	.	1.0	4.3	.0.0	41.7	183.9	127.5	136.1	273.3	9.1	1.0	31.5	809.4
1907–08	.	.	1.5	39.1	2.0	122.9	138.2	110.5	34.8	7.6	29.7	0.2	486.5
1908–09	.	.	2.3	24.9	46.5	66.6	333.0	235.2	92.5	0.5	.	.	801.5
1909–10	.	.	19.8	34.0	87.1	183.9	85.8	47.0	97.0	10.4	0.2	0.5	565.7
1910–11	.	.	1.5	15.2	22.1	45.7	406.2	102.9	131.3	39.6	6.9	1.0	772.4
1911–12	.0.0	.	.0.0	18.5	11.7	63.8	92.7	13.7	75.2	37.3	39.6	21.6	374.1
1912–13	.	.	37.1	17.8	98.8	41.2	96.0	16.3	50.3	14.5	25.2	.0.0	397.2
Averages	0.5	1.0	15.3	36.8	65.7	104.1	145.5	101.9	122.8	36.9	29.0	5.4	664.9

NOTE.—In accordance with the recommendation of the International Meteorological Committee absence of precipitation is indicated by a dot(.); a trace, amount too small to measure, by the symbol .0.0.

TABLE IVa.—MONTHLY AND SEASONAL PRECIPITATION, 1887–1913, IN INCHES

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal
1887–88	0.01	.	0.40	.	0.76	2.94	5.84	1.92	4.50	0.20	0.42	0.50	17.49
1888–89	.0.0	.	0.59	0.02	2.71	3.79	0.78	0.54	7.58	0.72	1.50	0.06	18.29
1889–90	.	.	.	5.80	2.39	12.59	11.16	5.70	4.74	2.18	1.44	.0.0	46.00
1890–91	.	.0.0	0.25	.	.	3.32	1.13	10.68	3.17	3.42	1.61	0.38	23.96
1891–92	0.44	.	0.74	0.18	1.01	6.22	2.34	4.20	3.60	1.68	2.97	.	23.38
1892–93	0.01	.	0.07	1.99	5.35	6.64	3.90	3.28	6.19	1.62	0.26	.	29.31
1893–94	.	.	0.38	0.52	5.22	2.62	9.54	3.77	0.91	0.57	2.01	1.11	26.65
1894–95	.	.	1.61	3.29	1.35	12.63	10.88	3.25	2.64	2.30	1.06	.	39.01
1895–96	0.04	.	1.28	0.07	1.78	2.20	11.40	0.36	2.93	6.72	0.94	.	27.72
1896–97	.0.0	0.90	0.76	1.91	5.15	4.92	3.71	4.68	5.97	0.44	0.20	0.30	28.94
1897–98	.	.	0.20	2.48	1.58	2.71	1.54	3.28	0.31	0.19	1.87	0.24	14.40
1898–99	.	0.04	0.93	1.88	0.97	1.22	5.90	0.22	13.19	1.56	1.70	0.05	27.66
1899–1900	.	.0.0	.	5.26	5.85	3.46	4.18	1.02	3.00	1.58	0.91	0.08	25.34
1900–01	.	0.02	0.05	1.41	5.04	1.83	5.86	5.91	0.91	3.06	1.02	.	25.11
1901–02	.	.	1.30	0.68	3.16	1.48	1.36	10.47	4.17	1.55	1.69	.	25.86
1902–03	.	.0.0	.	2.35	3.21	3.69	5.17	2.05	7.81	1.11	0.02	.0.0	25.41
1903–04	.	.	.	0.50	5.89	2.19	1.40	10.45	11.04	2.10	0.02	.0.0	33.59
1904–05	.	0.07	4.44	3.39	2.23	2.03	5.58	2.56	4.25	1.37	3.43	.	29.35
1905–06	.	.	.	.	1.46	2.22	6.92	3.96	9.05	0.74	2.56	0.64	27.55
1906–07	.	0.04	0.17	.0.0	1.64	7.24	5.02	5.36	10.76	0.36	0.04	1.24	31.87
1907–08	.	.	0.06	1.54	0.08	4.84	5.44	4.35	1.37	0.30	1.17	0.01	19.16
1908–09	.	.	0.09	0.98	1.83	2.62	13.11	9.26	3.64	0.02	.	.	31.55
1909–10	.	.	0.78	1.34	3.43	7.24	3.38	1.85	3.82	0.41	0.01	0.02	22.28
1910–11	.	.	0.06	0.60	0.87	1.80	15.99	4.05	5.17	1.56	0.27	0.04	30.41
1911–12	.0.0	.	.0.0	0.73	0.46	2.51	3.65	0.54	2.96	1.47	1.56	0.85	14.73
1912–13	.	.	1.46	0.70	3.89	1.62	3.78	0.64	1.98	0.57	0.99	.0.0	15.63
Averages	0.02	0.04	0.60	1.45	2.59	4.10	5.73	4.01	4.83	1.45	1.14	0.21	26.18

NOTE.—In accordance with the recommendation of the International Meteorological Committee absence of precipitation is indicated by a dot(.); a trace, amount too small to measure, by the symbol .0.0.

The monthly and seasonal amounts of precipitation for the twenty-six years of the record are comparable, as there has been no change in exposure which interferes with the homogeneity of the record. In the monthly precipitation for 1912–13 no maxima or minima for the individual months were recorded during the season.

Table V.—Monthly and Seasonal Precipitation for 1912–13 With Averages for Twenty-Six Years and Departures From the Averages

	Monthly		Seasonal to end of month		Average seasonal		Departure 1912-13	
Month	mm.	in.	mm.	in.	mm.	in.	mm.	in.
1912								
July	.	.	.	.	0.5	0.02	— 0.5	— 0.02
August	.	.	.	.	1.5	0.06	— 1.5	— 0.06
September	37.1	1.46	37.1	1.46	16.8	0.66	+ 20.3	+ 0.80
October	17.8	0.70	54.9	2.16	53.6	2.11	+ 1.3	+ 0.05
November	98.8	3.89	153.7	6.05	119.3	4.70	+ 34.4	+ 1.35
December	41.2	1.62	194.9	7.67	223.4	8.80	— 28.5	— 1.13
1913								
January	96.0	3.78	290.9	11.45	368.9	14.35	— 78.0	— 3.08
February	16.3	0.64	307.2	12.09	470.8	18.54	—163.6	— 6.45
March	50.3	1.98	357.5	14.07	593.6	23.37	—236.1	— 9.30
April	14.5	0.57	372.0	14.64	630.5	24.82	—258.5	—10.18
May	25.2	0.99	397.2	15.63	659.5	25.96	—262.3	—10.33
June	.0.0	.0.0	397.2	15.63	664.9	26.17	—267.7	—10.54
1912-13								
Season	397.2	15.63	397.2	15.63	664.9	26.17	—267.7	—10.54

Note.—Absence of precipitation (.); trace, .0.0.

Although there was an excess of rain in September and again in November, the amounts in all the other months were smaller than the average; and there was a cumulative condition of drought added to the dryness with which the year began as the season of 1911–12 ended with about one-half the average amount. The actual seasonal departure at the end of each month is shown by Table V, and graphically by figure 5. At the end of the season, June 30, 1913, the total rainfall for the twelve months was but 60 per cent of the average for the year, and this in spite of the fact that the average for the rainfall year had been somewhat decreased by the addition of two dry years to the record.

The shortage of precipitation for the year amounted to 267.7 millimeters, 10.54 inches.

The most unusual precipitation phenomena of the year were the occurrence of snow during the forenoon of January 9 and a thunderstorm between midnight and 1 A.M. on January 15. The snow generally melted as it fell and in no part of Berkeley remained long on the ground, although the hills were white during the day. The thunderstorm occurred in the middle of

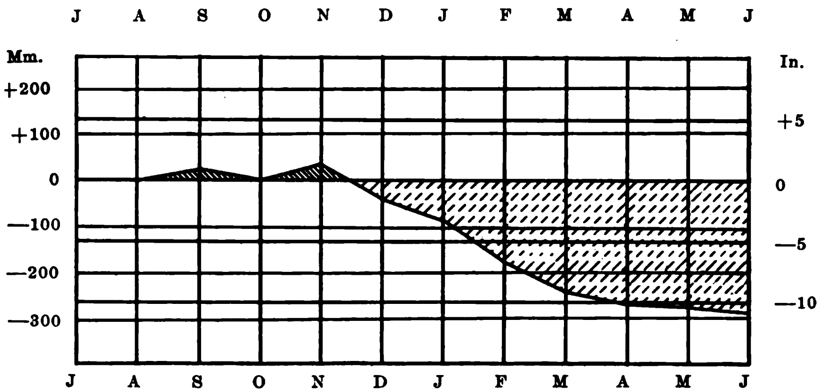

Fig. 5.—Accumulated monthly departures from average seasonal rainfall at Berkeley, California, of the seasonal rainfall for the year ending June 30, 1913.

a cyclonic rain period which lasted about a week (see Table VI on page 293.

DAYS WITH SIGNIFICANT PRECIPITATION

Table I shows the number of days with precipitation amounting to 0.25 millimeter, 0.01 inch, or more, of which there were fifty-eight during the year, and also the number of days with 1.0 millimeter, 0.04 inch, or more, of which there were forty-six. The average for the twenty-six years is sixty-five days, with 0.25 millimeter, 0.01 inch, and fifty-three days with 1.0 millimeter, 0.04 inch. These days are those on which the amounts were collected by the rain-gage; there may have been a few other days on which the amounts fell, but the catch of the gage is probably not far from the true amount of rainfall. On certain

days, which number about five for the year, the precipitation was collected from fog, but the total amount from this source is small, probably not over 1.25 millimeters, 0.05 inch, for the whole year. All the other days on which 0.25 millimeter, 0.01 inch, was collected are to be regarded as true rainy days, especially those on which more than 1.0 millimeter, 0.04 inch, was recorded, as in no case did the precipitation from fog much exceed the minimum measurable amount.

Figure 6 on page 291 may be read from two points of view, that of the per cent of days in each month with precipitation and that of the per cent of days in each month without precipitation. The shaded area shows the average probability of rainy days, that is, the percentage of days in each month when precipitation of 0.25 millimeter, 0.01 inch, may be expected, if the past is a measure of probability. The scale for rain probability is at the left of the diagram. The heavy line shows the percentage of days with rain in each month of the season of 1912–13. The diagram may also be read from the point of view of non-rainy days; in this case the blank area represents the probability of days without rain for each month when referred to the scale at the right, which reads downward, and the area above the heavy line represents the percentage of non-rainy days for the season ending June 30, 1913. A diagram of this kind shows more clearly than in other ways the fact that even in the so-called rainy season two-thirds of the days are on the average without rain of significant amounts.

The number of days with precipitation during the past year was greater than the average in the months of September, October, November, January, and May, and was less than the average in the other months. In the long run the curve of monthly rain probability will closely resemble the curve of average monthly amounts of precipitation, but in individual years there may be a wide difference between the two curves. In spite of this, a comparison of figures 4 and 6 shows some features in common, although the two curves cannot be said to be alike.

The maximum amounts of precipitation for each month and for the year may not be strictly accurate in all cases, as the

measurements of precipitation have all been made at the observation hours only. There is no doubt, however, that they are in general somewhere near correct, and that the greatest amount

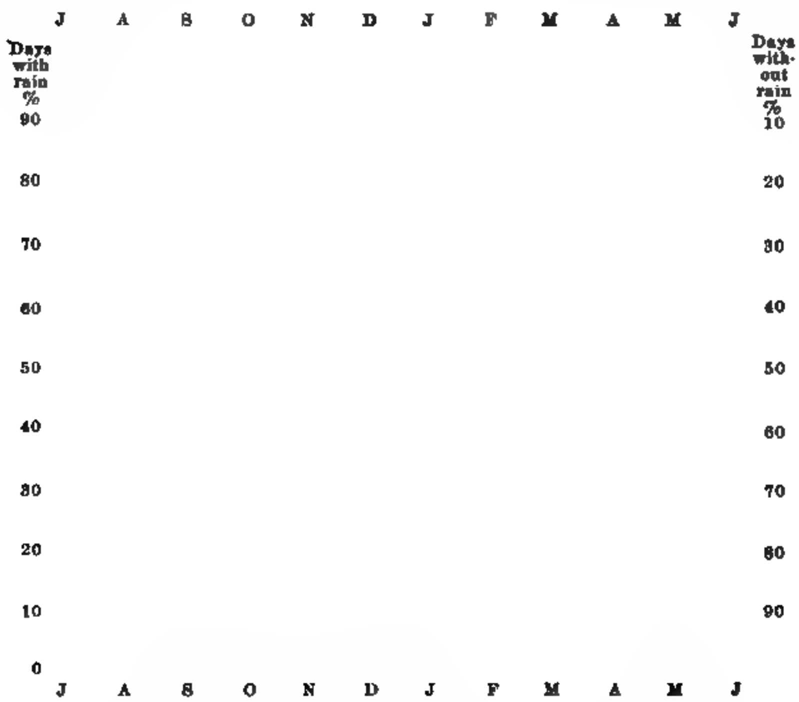

Fig. 6.—Average probability by months of days with significant precipitation (0.2 millimeters, 0.01 inch or more) at Berkeley, California; and per cent of days with significant precipitation, 1912–13 (scale at the left). Also average probability of days without significant precipitation, and per cent of days without significant precipitation, 1912–13 (scale at the right).

Shaded area indicates probability of rainy days.

Heavy line indicates per cent of days with rain, 1912–13.

in a single day during the year occurred in a twenty-four hour period ending at some time on November 6, and that the amount for this period approached sixty-five millimeters, two and a half inches. This amount, while large for a single day, cannot be regarded as extreme for Berkeley, as it has been exceeded in each of the months of the rainy season at some time during the past twenty-six years. At no other time during the year did

the precipitation on a single day exceed twenty-five millimeters, one inch.

CYCLONIC PRECIPITATION

Although practically all the rain at Berkeley is the result of cyclonic activity, it has not been easy in all cases to assign the precipitation of a given day to a particular cyclone. In fact, the cyclonic relations in the Pacific Coast region are somewhat complicated, rather important pressure fluctuations taking place while a single cyclone seems to be the dominant control of the weather, instead of the simpler fall in pressure as the cyclone approaches and the rise in pressure after the center has passed. In view of the importance of the cyclone as the control of precipitation at Berkeley, Table VI has been constructed. This table includes all the precipitation for times at which depressions or unsettled conditions of pressure could be determined from the barograph trace. By a somewhat liberal interpretation it has been possible to include under the eighteen cyclones given in Table VI precipitation amounting to 394.4 millimeters, 15.52 inches, or all but 2.8 millimeters, 0.11 inches, of the total for the year. Of this amount 1.0 millimeter, 0.04 inch, was from fog, which leaves only 1.8 millimeter, 0.07 inch, of the rain not accounted for by cyclones. This amount was all recorded on April 12, and is shown by the weather maps to be almost surely of cyclonic origin; it has been omitted from Table VI because the barograph trace does not show clear cyclonic characteristics.

In constructing Table VI the occurrence of precipitation was used as a basis; no account was taken of cyclones which appeared on the weather maps or which were indicated by the barograph trace, unless precipitation occurred at Berkeley. There were several cases where no unsettled pressure condition would have been revealed by a casual inspection of the barograph trace, but in all the cases in the table the trace for the dates of precipitation, when carefully examined, showed at least an unsettled pressure condition. In many cases the limiting dates shown in Table VI were determined by the precipitation, but in about half these dates were somewhat extended from the evidence of the barograph trace.

TABLE VI.—CYCLONIC RAINFALL, 1912–13, BERKELEY, CALIFORNIA

No.	Date	Precipitation mm.	Precipitation in.	Barograph Trace	Weather Map Notes
1	Sept. 2	2.3	0.09	Faint depression	Low over Vancouver 2nd; breaking up 3rd
2	Sept. 5–6	34.8	1.37	Faint depression	Low off Washington coast, moving east
3	Oct. 22–29	17.8	0.70	Unsettled	Strong low off Washington 21–23rd, moving east; low crossing Washington 24–26th; lows in southern plateau states and Washington 26–29th
4	Nov. 3–10	90.1	3.55	Unsettled with two moderate depressions	Lows crossing Washington and Oregon; subordinate lows in Nevada
5	Nov. 12–15	1.3	0.05	Moderate depression	
6	Nov. 18–20	7.4	0.29	Moderate depression	Low crossing southern British Columbia
7	Dec. 13–17	38.4	1.51	Marked depression 14th and 15th	Large low crossing southern British Columbia
8	Dec. 30–31	2.8	0.11	Weak depression	Large low off coast of northwestern United States
9	Jan. 7–11	20.1	0.79	Marked depression	Low in northwestern states, later in the plateau states
10	Jan. 11–19	74.7	2.94	Marked depression 11–17th, unsettled 17–19th	Large low central in northwestern states, moving east
11	Jan. 20–23	1.0	0.04	Marked depression	Follower of the preceding, moving east
12	Feb. 5–10	2.8	0.11	Marked depression	Marked low crossing southern California
13	Feb. 20–28	12.7	0.50	Moderate depression 20–22nd, marked depression 23–28th	Large low area central in British Columbia and Arizona, later in California, northwest and plateau states, Oregon, California, and moving east
14	Mar. 15–25	50.3	1.98	Depressions: marked 15–18th, unsettled 18–21st, weak 21–26th	Low in British Columbia and Washington with trough to Arizona; moving east
15	Apr. 2–8	12.7	0.50	Weak depression	Low in British Columbia
16	May 8–9	5.6	0.22	Very faint depression	Weak low in northwestern states
17	May 15–19	8.9	0.35	Faint depression	Low over Nevada, moving east
18	May 27–29	10.7	0.42	Very weak depression	Low over Nevada

After studying the barograph trace in connection with the precipitation dates, the daily weather maps for these dates were examined for evidences of cyclones which were in a position to be effective as precipitation controls for Berkeley; these cyclones have been briefly noted in Table VI. As with the barograph trace, no attempt has been made to work from the occurrence of cyclones, as shown by the weather maps, to precipitation at Berkeley, but merely to assign as far as possible the Berkeley rainfall to the proper cyclone. Thus far no correlation has been attempted beyond the mere fact of precipitation at Berkeley and the indication of cyclonic pressure conditions at the station and the appearance of a cyclonic area on the daily weather maps.

Of the eighteen cyclones seven were clearly shown by a marked depression of the barograph trace at the time of precipitation. During the rainy season, December to March inclusive, there were eight cyclones which are included in the table, and the seven with marked barometric depressions are included in this eight. The maps show in some cases, notably numbers 4 and 5 of Table VI, that the areas of low pressure cannot be clearly separated from each other. It is possible that the evening map, or barograms from stations with a central passage, would make a separation practicable, but such a study is outside the scope of the Berkeley station report. The maps show that number 11 of the table is probably due to the same general disturbance as number 10, but the precipitation and the barograph trace at Berkeley indicate a separation; and as the weather maps do not show that the same cyclone persisted, the two have been kept separate. The heaviest cyclonic rainfall averaged about eighteen millimeters, seven-tenths of an inch, a day, and the lightest averaged about half a millimeter, two one-hundredths of an inch, a day for the whole duration of the cyclone.

As the problem of cyclonic weather control is not as yet worked out for Berkeley, this expression of the cyclonic rainfall relations is offered as a suggestion of what may be done and with the hope that these relations may be more accurately determined, so that the Berkeley record may in time give more completely than has yet been possible an accurate account of the most important single control of weather for places outside the

meteorological tropics. The "meteorological location" of Berkeley, except, perhaps, during the summer months, is on the poleward side of the meteorological tropics, and because of this the cyclonic unit is in a large measure the factor which controls the meteorological conditions.

WIND DIRECTIONS

Observations of wind direction have been made at the morning and evening hours; the results are tabulated under the heading "Winds at 8 H. and 20 H. (number of observations)" in Table I. This part of the table shows the winds actually observed on the Campus in the morning and evening as far as they can be determined. All wind directions at Berkeley must be estimated, as the equipment of the station does not include a vane and no accurate compass directions have been laid down on the Campus. In general the observations have been made from the drift of smoke and from the flag on the Campus, so that the directions must be regarded as approximations and not the actual conditions of air movement. These give fairly accurate directions for the morning hour, but the directions are more uncertain at night.

From the topography of Berkeley and its vicinity, as shown by the map on page 296, figure 7, it will be seen that there is probably a strong local influence on the wind direction, which may amount to actual control in some cases. Figure 7 and plate 31 show the general trend of the hills, and the observed southerly winds may be in part due to this trend. The cañon of Strawberry Creek through the western line of hills bordering the Campus must have some effect on the wind direction. Although no detailed study has been made of the local air drainage, it is certain from casual observations that there is frequently in the evening a draft down from Strawberry Cañon across the Campus. There are, however, no observations which show whether there is an up-cañon draft in the daytime. It would not be surprising to find that the trend of the faces of the hills and the existence of Strawberry Cañon exert a marked influence on the direction of the wind at the University Campus.

The winds observed during the year 1912–13 showed a marked tendency to blow from a southerly direction: of the seven hundred and thirty observations of wind, four hundred and fifteen

Fig. 7.—Topographic map of Berkeley, California, and its vicinity, showing the relation of the exposure of the meteorological instruments on the Campus of the University of California, the Berkeley Hills and the valleys in the hills; and also the topographic relations which are probably effective as controls of wind direction. Scale about 1:67,000; contour interval 100 feet, 30 meters. Datum is mean sea-level. From portions of the San Francisco and Concord, California, Sheets, United States Geological Survey.

were of wind from a southerly direction, and of these two hundred and eighteen were from the south. This was true of both morning and evening observations. The prevailing wind was from the south at the morning observation in all months except August, May, and June, when it was from the southwest, and February, when it was from the north. South winds prevailed at the evening observation hour in all months except July, August, March, May, and June, when the prevailing wind was southeast. Calm has been recorded with slightly more frequency at the morning than at the evening hour, but not enough to enable any conclusions to be drawn either as to the existence of calms or as to the accuracy of the observations.

The wind controls at Berkeley are cyclonic modifications of the prevailing westerlies in winter and the pressure relations between the oceanic high pressure area of the North Pacific Ocean and the thermally controlled continental low pressure area over North America. As most of the cyclone paths are to the north of Berkeley, the cyclonic winds are generally from a southerly direction. Anticyclones have less well defined paths, with a tendency to occur farther south than the cyclones, so that there were not compensating northerly winds under this control.

Of the observations of wind twenty-nine from the south in November was the largest number from a single direction in any month during the year, although calm was recorded in May at twenty-nine observations. In March there was a good deal of southeast wind. Calm was recorded more frequently than any single wind in August and May. Northerly winds were recorded with more than average frequency in November, February, March, and April.

Because of the possibility of temporary control of the wind direction at the observation hours, the prevailing wind for each day has been recorded. This is subject to some error because the idea of prevailing wind is the result of cumulative impressions based on irregular observations through the day and recorded in the evening; but it is probable that the general direction for the day is generally reasonably accurate. From the daily record of wind direction the portion of Table I headed "Prevailing Wind (number of days)" has been compiled. This part

of the table shows a preponderance of wind from the south during the winter months and from the west and southwest in all other months except July, when the prevailing directions were southwest and south. Calm days, that is, those practically without wind, have been recorded seven times during the year; on many other days the velocity was very small, but, as the station is not equipped with an anemometer, no record of velocity is published. The prevailing winds are shown for the year by the wind-rose, figure 8; this has been constructed on the basis of the year only,

Fig. 8.—Prevailing daily wind directions at Berkeley, California, 1912-13. Circles indicate number of days.

and represents the number of days on which the wind was prevailingly from each direction; no account has been taken of the seven calm days. The striking feature of this wind-rose is the very large preponderance of winds from the southwesterly quadrant; of the total days of the year the prevailing winds on two hundred and seventy-five, about three-quarters, were from this quadrant.

The relations between prevailing winds and cloud and rain should be determined, but the equipment of the station is not sufficient to justify such a correlation as yet. Casual observations indicate greater cloud and rain with south and southeast winds, and least with northerly winds. West and southwest winds are sometimes accompanied by clear days and sometimes by days with considerable cloud, but rarely by days with rain.

CONCLUSION

The mean annual temperature at Berkeley during the year 1912–13 was about 287° A, 57° F, with a mean annual range of 10° A, 19° F, and an extreme range of over 40° A, 70° F. The mean maximum temperature was 292° A, 66° F, and the mean minimum 281° A, 47° F. The mean monthly range was 21° A, 38° F, the mean daily range 10° A, 19° F, and the mean change from day to day 1.4° A, 2.6° F. September was the warmest month of the year and January was the coldest; January was probably abnormally cold, but no other month had a very unusual temperature. Frost was probably more frequent in December and January than the average for the whole period of the record for these months.

The pressure of the water vapor of the atmosphere was in general less than 13 millibars (10.0 millimeters or 0.4 inch of mercury), the relative humidity averaged slightly more than 80 per cent morning and night, and the mean dew-point was about 275° A, 36° F, in the winter and about 286° A, 56° F, in summer. The vapor pressure and the dew-point showed a strong tendency to vary with the air temperature. Not quite half the days of the year were generally clear, but only a quarter of the days were generally cloudy and many of the partly cloudy days

had several hours of bright sunshine. Fog was observed on forty days and "high fog" on about as many more, which is probably about the average for Berkeley.

The total precipitation for the year was 397.2 millimeters, 15.63 inches, which is 267.7 millimeters, 10.54 inches, less than the average. September and November had more than the average rainfall, but all the other months had less than the average. Snow fell on one day in January. There were fifty-eight rainy days during the year, which is slightly less than the average; in five months of the year there were more than the average number of rainy days, and in five there were less than the average number, July and August being omitted from consideration, as they are generally dry. The heaviest fall of rain in any one day of the year was 60.7 millimeters, 2.39 inches, on November 6; this was the only day on which as much as twenty-five millimeters, one inch, fell. The precipitation of the year was mainly the result of eighteen cyclones, the centers of most of which passed far north of Berkeley, but the cyclones were near enough or large enough to control the weather at the station.

The wind was generally from southerly and westerly directions in the average for the year, both in the prevailing directions by days and at the observation hours. The westerly element was more marked in the summer months. Calm days were rare, although no wind movement was observed at about one-fifth of the observation hours.

Transmitted August 25, 1913.

PLATE 29

Fig. 1.—Location of instrument shelter (right) and rain-gage (left) at the Students' Observatory on the Campus of the University of California, Berkeley, looking east. The trees are about the same distance from the instruments on all sides except the south.

Fig. 2.—United States Weather Bureau Co-operative Observers instrument shelter from the northwest. The hill on the south slopes steeply 10 meters, 40 feet, to a small cañon (see text-figure 2, page 256), thus affording good air drainage so that the minimum air temperatures on the Campus are not recorded in the shelter.

Both photographs were taken from the roof of the building west of the main building of the Observatory (see fig. 1, page 249).

PLATE 30

Rain-gage at the Students' Observatory on the Campus of the University of California, Berkeley, elevation 100 meters, 325 feet, above sea-level, 4.6 meters, 15 feet, above the ground, showing the relation of the roof to the gage. The height of the smaller building to the west (see text-figure 1, page 249), from which this photograph was taken, is the same as that on which the gage is located.

UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY

Vol. 1, No. 7, pp. 307-330, pls. 32-36 August 7, 1914

PRELIMINARY REPORT ON THE RECENT VOLCANIC ACTIVITY OF LASSEN PEAK

BY

RULIFF S. HOLWAY

CONTENTS

INTRODUCTION

The recent formation of a new crater on the old cone of Lassen Peak is, so far as the writer knows, the first recorded instance of undoubted volcanic activity actually witnessed within the limits of the United States, if territory not contiguous be excluded. It is not surprising therefore that both popular and scientific interest have been greatly aroused as to the nature and extent of the real changes which have taken place. At first it was difficult to secure reliable reports, for the region about the mountain is sparsely settled, and this year, on the date of the first eruption, May 30, the snow was still very deep, obscuring

all roads and trails as low down as the six thousand-foot contour line. On account of the unusually late season, the summer influx of cattlemen, lumbermen and campers had not yet begun; probably the nearest occupied house was at least eight miles distant in an air line from the mountain top. The inhabitants of the neighboring region were unfamiliar with volcanic phenomena and very naturally observations from stations ten to fifty miles distant resulted in the first reports being conflicting and confusing.

Considering all these circumstances, it seems advisable to issue this preliminary report even though at this date it is necessarily incomplete, and even though the probability may be strong that the eruptions have by no means ceased.

GEOGRAPHIC RELATIONS

Lassen Peak is in the southeastern part of Shasta County, in Northern California, about two hundred miles from San Francisco. According to the Lassen Peak topographic sheet (a reconnaissance map surveyed in 1882–84), the mountain is ten thousand four hundred and thirty-seven feet in elevation and is approximately in latitude 40° 30′ N and longitude 121° 30′ W. The immediate region lies on the extreme southwestern edge of that great tertiary lava flow some two hundred and fifty thousand square miles in extent which covers not only northeastern California but portions of Oregon, Washington, Idaho, and Nevada.

In general, geographers consider Lassen Peak as marking approximately the southern end of the Cascade Range, and as being the last of that series of great volcanic cones of which Rainier, Adams, Hood, Three Sisters, Pit, Mt. Mazama, and Shasta are familiar examples. To the southeast of Lassen is the topographic gap of the Feather River separating the Cascade Range from its correlative, the Sierra Nevada, which extends four hundred miles farther to Tehachapi Pass but whose lofty peaks owe their height primarily to uplift rather than to volcanic upbuilding.

PAST HISTORY

The southern fifty miles of the Cascade Range extending northwesterly toward Shasta from the North Fork of the Feather River is a great volcanic ridge, about twenty-five miles wide, studded with numerous minor volcanic cones and culminating in Lassen, the dominating peak, guarded by a half dozen other major cones which rise to heights varying from seven thousand to nine thousand feet above the sea. Past volcanic phenomena of the Lassen Peak region in recent geologic time have been made familiar to readers through J. S. Diller's well-known report,[1] which describes with considerable detail the Cinder Cone, ten miles northeasterly from the main peak, from the base of which the latest lava flow issued. Until the present outbreak, despite our knowledge of the Cinder Cone lava flows, it has been tacitly assumed in physiographic literature that Lassen Peak belonged to the class of extinct volcanoes, although the following statement by Diller in the folio just quoted shows clearly that twenty years ago he recognized the possibility of renewed eruptions.

"The volcanic action which has built up Lassen Peak with its many associative cones is comparatively recent. It began at the close of the Ione epoch and occurred most violently at the time the Sierra Nevada was upheaved, but it has continued spasmodically to the present time. . . . The latest volcanic eruption in the Lassen Peak district, and possibly the latest in the United States south of Alaska, occurred at the Cinder Cone about two hundred years ago. Some of the trees killed at the time are still standing. The lava, although very viscous, spread more than a mile from the vent and formed a huge tabular pile which extends across a little valley. The lava dam thus formed developed Snag Lake, which contained stumps of some of the trees drowned at the time the lake originated.

"That volcanic activity is not yet extinct in the Lassen Peak district is shown by the presence of numerous solfataras and hot springs. At Bumpass's Hell, near the southern base of the peak, there are boiling mud pools and vigorous solfataric action. Near by, at the head of Mill Creek, the sulphur deposited by

[1] Lassen Peak Folio, U. S. Geol. Survey, 1894.

such action is so abundant that attempts have been made to mine it. Similar phenomena occur in Hot Spring Valley and at Lake Tartarus and the Geyser, near Willow Lake. The Geyser is much less vigorous than formerly, and now the column of water rises scarcely a foot above its pool."

PRESENT VOLCANIC ACTIVITY

The present volcanic activity of Lassen Peak began the latter part of May. Prompt investigation of the real condition of affairs is due to the fortunate fact that the mountain is included in the Lassen Peak National Forest and that the United States Forest Service[2] had built a fire lookout station on the topmost crag of Lassen Peak itself. The headquarters of the Forest Supervisor, Mr. W. J. Rushing, are in Battle Creek Meadows, near Mineral postoffice, a little more than ten miles in an air line from the top of the mountain. The lookout house on Lassen and the other stations also are connected with the Supervisor's headquarters by the government telephone lines which extend to the town of Red Bluff, nearly fifty miles to the westward, giving direct, communication with San Francisco. When the eruptions began the fire lookout station on Lassen had not as yet been occupied for the summer season of 1914, but it was the property of the Forest Service and a station of special importance. It will be seen that the interests and resources of the Forestry Service as indicated above were such that reports of volcanic activity on Lassen were investigated at once and definite records kept of the reports brought in to headquarters. The newspapers of June 2 gave to the general public its first intimation of the volcanic outbreak. As Lassen is visible from fifty to sixty miles in all directions to places favorably situated, the reports of the same eruption seen from different points of view were frequently contradictory. In some of the accounts flames and molten lava were graphically described and such startling reports were either still further exaggerated or the entire occur-

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[2] The writer is glad to express his appreciation of the assistance and courtesies extended him in connection with his field work not only by District Forester DuBois, of San Francisco, and Supervisor Rushing, of Mineral, but also by various members of the staff in each place.

rence unduly discredited according to the temperament of the reader. The continuation of these reports finally convinced the public that unusual phenomena of a volcanic nature were taking place on the mountain, but it was a difficult task to sift and correlate the various accounts published. Earthquake shocks were reported in some of the earlier eruptions, especially from the region to the eastward of Lassen Peak. Later eruptions were apparently entirely free from seismic disturbances. The following extracts from the report of Forest Supervisor W. J. Rushing to the District Forester at San Francisco, made June 9, give the best summary yet available of events up to that date.

LASSEN—SUPERVISION.

MINERAL, CAL.,
June 9, 1914.

District Forester, San Francisco, Cal.,

DEAR SIR:—Such wild stories are being circulated concerning Mt. Lassen that I am sending you the results of our observations to date.

Saturday, May 30, the first outbreak occurred at 5 p.m.. This was witnessed by Bert McKenzie, of Chester, who was looking directly at it when it occurred. Ranger Harvey Abbey investigated it Sunday, May 31, finding a hole 25 x 40 feet in size and of unknown depth. Sand, rocks as large as a sack of flour, and mud had been ejected. The heavier material was thrown over an area three hundred feet across, while the ash, or cement-like material, was scattered over an area one-quarter mile across. . . . No molten material was thrown out at all.

8:05 a.m., June 1, a second outburst occurred, throwing out large quantities of the same material. Some boulders weighing all of a ton were thrown out. The vent was enlarged to 60 x 275 feet. . . . Boerker, Abbey, and Macomber went up June 4, remained on top at the lookout house over night, and came back June 5.

June 8 heavier volumes of steam were noted, and at night apparently another eruption took place, throwing out more ashes or fine material, which could be seen on the new snow.

Heavy volumes of steam are coming out of the vent today. We have watched it carefully and at no time have we been able to see any flame or indication of fire. . . .

The vent is about one-quarter mile from the fire lookout house, and if it continues eastward, as it has so far, it will finally break out on the east side.

No damage has been done to the house yet, and if the action does not become more violent will not prevent a lookout occupying it.

Very truly yours,
(Signed) W. J. RUSHING,
Forest Supervisor.

Mr. Ben Macomber, one of the party mentioned in the report above as spending the night on the mountain top, has given the following description of the crater as it was after the early eruptions:

When I saw the new crater on Lassen on June 4th and 5th the vent, by an engineer's tape, measured 275 feet long. It was then in one of the pauses between the heavy explosions. Thick volumes of steam, laden with sulphur smoke, were rising, and cracks were appearing in the ground. From three different places on the edge I looked down into the crater. Sixty or seventy feet down a pile of rocks was visible in the center of the vent, but at either end was a huge dark hole from which the steam clouds poured. The walls were absolutely perpendicular, and around the top were hung with huge icicles formed by the condensation of steam in the chill air of the peak.

On the west side of the crater everything was buried beneath a heavy fall of light gray ash, into which we sank over our boot-tops. So light was this rock powder that it flew into the air at every step. On the east side the same material seemed to have been thrown out in the form of mud and lay frozen hard as rock. What little snow remained near the crater was buried under a layer of stones and boulders. The larger boulders had sunk down into the snow, creating many treacherous pits.[3]

EXPERIENCES NEAR THE CRATER DURING ERUPTIONS

An interesting series of eruptions occurred June 12, 13, and 14. On Friday, the 12th, Forest Ranger Abbey and a party of five were "climbing upward half a mile from the crater, when with a great roar the mass of ashes and boulders shot into the sky above." Immediately stones began to fall about them, and three hundred-pound boulders began to drop a short distance above and bound down the mountain side toward them. The party ran to shelter behind a point of rocks on the ridge. Milton A. Ayres, the San Francisco moving picture operator, alone faced the storm. Setting up his machine on a boulder, he began to turn the handle. That night he told the story of his experiences at the volcano.

We had no warning. The roar and the uprush of the black mass above were simultaneous. The rocks began to fall on the mountain side; the gases did not come our way much, as the wind drove them to the east, but we got some strong whiffs of sulphur smoke. For the same reason little ash fell where we were. . . .

[3] San Francisco *Chronicle*, June 28, 1914.

Later we went on to the summit, reaching it at 6 p.m., two hours after the eruption began. We found the whole mountain top strewn with great boulders and heavy ash. No one could possibly have lived at the top while the outburst was on. We climbed up to the shelter house, where we had expected to spend the night, and found it in ruins. Boulders had crashed down through it and splintered the building to kindling wood.[4]

On the way down the next morning another eruption took place at 6 a.m., lasting thirty minutes, during which ashes fell at the headquarters of Forest Supervisor Rushing.

The eruption of June 14, the third day of this series, was the heaviest yet reported. The only injuries suffered by visitors to the crater occurred in the outburst beginning about 9:45 a.m. On that morning a party of eight were climbing the mountain from Manzanita Lake.

They reached the crater in safety, looked down upon it, and, noting the heavy outpouring of steam and smoke that boiled up between the three peaks that mark the ruined walls of the ancient crater, decided to get away as quickly as possible. They were too late; hardly had they gone a quarter of a mile from the crater when the black mass of rock and ash rushed up from the crater with a mighty roar and stood high above them. They ran in terror before the awful threat, but there was no refuge. With a crash the hail of rock fell upon them. At the same moment the storm of ash came down with midnight blackness. As the men ran down the slope they lost each other in the darkness. When the survivors came out of the storm and met below the line of rock and ash four men were missing. For two hours explosion followed explosion in one continuous crash.

In the rest of the dispatch one of the party, Lance Graham, was reported to have died of his injuries. Later reports stated that he was found unconscious, and was later left for dead, but he was finally taken down the mountain side and is now reported convalescent. He was severely injured, the bones of the shoulder being broken and the flesh badly bruised. The other men temporarily lost finally reached camp in safety. Considering the difficulty of getting accurate accounts, especially when in most cases there necessarily was repetition in transmitting the news, it is not surprising that the first accounts contained many inaccuracies. The portions quoted were selected because subsequent events showed them to be practically correct, although an inspec-

[4] San Francisco *Chronicle*, June 14, 1914.

tion of plate 34 does not justify the statement that the fire lookout house was splintered to kindling wood. The quotations, however, undoubtedly fail to give a correct impression of the grandeur of the phenomena or of the terror which they must have inspired in the observers within the danger zone.

The best pictures of Lassen Peak taken during an eruption are possibly those obtained on the morning of June 14 by Mr. B. F. Loomis. Four of these photographs are reproduced in plate 36, showing successive phases of the eruption. A letter from Mr. Loomis came after this paper was finished, but the major part of it is inserted here because of its great interest, even though some newspaper accounts of the same events have already been given.

VIOLA, SHASTA CO., CAL.,
July 13, 1914.

Mr. R. S. Holway, Berkeley, Cal.,

DEAR SIR:—Yours of the 3rd inst. is just received, in which you ask me to say a few words in regard to the eruption of Mt. Lassen. It affords me pleasure to comply with your request, as I know the information will be used for educational purposes.

Viola is situated about ten miles west of Mt. Lassen, and as I have climbed to the top of the mountain three times since the first eruption on May 30th I am fairly familiar with conditions as they exist there.

We had been camped on the road two days waiting for an eruption to occur, with camera focused and trained on the mountain all ready to begin taking pictures at a moment's notice. Mrs. Loomis enjoys landscape painting, and to get the colors properly it was necessary for her to witness an eruption. At about 9:45 Sunday morning, June 14, our vigilance was rewarded with success. I saw the smoke ascending from the crater the moment the eruption began. I ran to the camera, put in a plate holder and exposed, getting what we call photo No. 1. Then I changed the plate holder and exposed again as quickly as possible, getting photo No. 2. At this time a wonderful phenomena occurred. The heavy ashes contained in the column of smoke, its momentum being spent, began falling downward and flowed down the sides of the mountain, then rolling up in immense clouds of black smoke. This is slightly noticeable in photo No. 2. At this juncture I exposed again, getting photo No. 3. The wind was from the south, which blew the smoke to the left from my position and away from the top of the butte; then another cloud shot upward, when I exposed again, getting photo No. 4. These clouds of black smoke were so dense that they seemed to stand up like a mountain of granite in a solid mass. The sight was fearfully grand. The cloud was moving rapidly toward the north, when I soon got photo No. 5. These first five photos were taken with a telo-photo lens, 14-inch focus, and later,

when the cloud of smoke was all spread out, I got photo No. 6, this being made with the combined lens with 8½-inch focus, the size of the plates being 6½ × 8½.

This eruption of June 14th was the ninth eruption, and the time between photos No. 1 and No. 6 was about twenty minutes. These eruptions sometimes appear as a puff of smoke and ashes, and at other times they continue for about half an hour. The distance from my viewpoint to the top of Mt. Lassen is a trifle over six miles, according to the geological survey.

But in the midst of my enthusiasm in making the pictures I could not help thinking of those men who I knew must be near the mountain. Were they safe? Mr. R. E. Phelps and his mill crew, ten men in all, were camped at Manzanita Lake the night before. They struck camp early in the morning to climb the mountain to look at the crater. They went up on the north side right under where the heaviest smoke and ashes fell. Another party of five men also left the lake at 8 o'clock on the same mission. Mr. Phelps' party had just reached the rim of the old crater and sat down to rest a short time, watching the smoke from the crater, when the eruption began. Without any warning or explosion that could be heard, a huge column of black smoke shot upward with a roar, such as would be caused by a rushing mighty wind, and in an instant the air was filled with smoke, ashes and flying rocks from the crater. They all ran for their lives. Mr. Phelps hid under an overhanging rock, which sheltered him from the rocks which brushed past him as they fell. Lance Graham was a few feet away and was struck by a flying rock, which cut a great gash in his shoulder, piercing the thoracic cavity, and broke his collarbone. He was left on the mountain for dead, for a time, but was afterward removed with great difficulties, and is now recovered. Jimmy Riggins, another of their party, ran down the mountain and, coming to a snowdrift, slid down the mountain like a shot. The cloud of smoke kept pace with him, and when he reached the bottom of the snowdrift he found a clump of bushes and, diving into it, buried his face in the snow to keep out the blinding smoke and ashes. The smoke is described as causing the blackest darkness, black as the darkest night. If it had lasted much longer some of them would have been smothered.

One peculiarity is that all the rocks and ashes were cold, or only lukewarm. Had they been hot these men would have been burned to death. Later I learned also that the rocks which fell on the snowdrift inside the south rim of the crater are still lying on top of the snow where they fell, the snow being frozen hard when they fell, but they would have melted their way to the bottom had they been hot. This snowdrift is about 600 feet south from the new crater and there are probably a thousand rocks lying on top of the snow where they fell. This snow is covered with about three inches of ashes, which turn black when wet. It is seen in the foreground in my photo of the crater. . . .

Trusting that this brief description will be of service, I am

Very truly yours,

B. F. Loomis.

CONDITION OF THE CRATER JUNE 26 AND 28

The writer's observations were made in the interval from June 21–29, between which dates no eruption took place. On the 21st the mountain was approached from Mineral by way of Soupan Springs. During the day a continuous thin jet of steam was being emitted from the crater, but the camera failed to show the steam in the view taken from the peak just north of Soupan Springs, plate 33, figure 1. This view shows the top of Lassen as two minor peaks. On reaching the top these two minor peaks seen in perspective from the southwest are found to be two much eroded ridges which are undoubtedly remnants of the ancient crater walls.

From June 23 to 25, rainstorms, with snow on the higher levels, prevented a visit to the crater with any possibility for photographic work. On Friday, the 26th, and Sunday, the 28th, the sky was clear, and on both those days the actual crater was visited and photographed from various points of view. Both trips were made from the hotel at Morgan as a base (see map, plate 32). The ride on horseback to the foot of the volcanic cone proper at that time took almost four hours, the latter half being over snow from ten to twenty feet deep. The new crater has frequently been described as being located on the south slope of the north peak. North Peak, however, is merely the northern portion of the walls of the ancient crater. The relations of the new opening to the old volcano are better appreciated by describing it as an opening not in the center, but on the north side of the bowl of the old crater. The central depression of the old crater is probably over three hundred feet below the remaining points of the old rim. The wall of the old crater has been deeply breached both on the east and on the west, and the melting snow in the depression now drains westward, although there is not enough surface water to make any regular channel. The volcanic dust or "ash" from the different eruptions has been reported as falling from ten to twenty miles from the peak, the amount and direction evidently varying with the wind. Plate 33, figure 2, shows that the limit of the heavy fall of ash not wind-borne was quite definitely marked and was probably within a circle of

a half mile. It was not, however, a uniform circle. In making the ascent on June 26, instead of the regular trail a more easterly route was taken, leading up the southeasterly ridge directly to the fire lookout station. This ridge, which lies in the general direction of the longitudinal opening of the crater itself, was found to be much more heavily covered with ash than the regular trail. While the main outburst was directly upward in the eruption shown in plate 36, irregular streaks of ash such as the one just noted prove that there were minor outshoots of volcanic dust in various directions. Reports of the distance to which stones were thrown seem to have been based upon their being found resting upon the surface of the old snow, but the fact that stones are constantly being dislodged from the cliffs by ordinary weathering processes and are rolling down the mountain side shows the need of additional criteria. To avoid mistaking such stones for those thrown through the air by eruption, careful search was made on level patches of the old snow so located that stones could not well roll down upon them. Wherever such level surfaces were found there was no evidence of ejected stones falling a much greater distance than the lookout house.

The new route taken June 26 in climbing the last two thousand feet of Lassen presents some advantages in studying the mountain in relation to its volcanic activity. To the eastward can be seen the lava field of Cinder Cone and some half dozen other cones, several of them with the craters still well preserved. On reaching the narrow ridge which leads immediately upward to the fire lookout station, directly below to the northward there is seen an area of barren, burnt-looking rocks suggesting a local outpouring of lava in geologically recent time. The heavy deposit of recent ash through which one walks for the last twenty minutes extends but a moderate distance on either side of the ridge, indicating that this route to the top is directly in the line of fire of the crater above. Nearing the top, the crag upon which the Forest Service station is built becomes so steep and rugged that the final climb is made without any glimpse of what is ahead. As the last rocks are scaled and one stands on the few feet of space by the little frame building bound down to the crag by wire cables there suddenly yawns below the climber the

bowl of the ancient crater, and he looks directly into the irregular naked chasm of the new vent torn in the opposite slope. It is impossible for a camera with its narrow field of view to give correct impressions of the topographic conditions of the mountain top. The observer standing upon that sharp rocky pinnacle is conscious of the steep slopes behind him and, although he narrows his vision to the new crater steaming below, he sees subconsciously the surrounding ragged edge of the bowl of the ancient crater.

Descending into the irregular basin, the new vent was photographed at closer range from various directions. No appreciable change occurred between June 26 and June 28, except the rapid disappearance of the new snow as a result of the warmer weather. The northwesterly end of the new crater, plate 35, figure 1, was of most interest because of escaping steam. On close approach the sulphur fumes became oppressive and yellow sulphur deposits near the vents were distinctly noticeable. The crater was apparently being extended longitudinally along cracks at either end. The northern wall showed also a transverse crack running back from the vent more than a hundred feet, plate 35. The depth of the crater did not seem to be over eighty feet, but the continually caving sides suggested that the present bottom is but piled-up debris. No suggestion could be obtained of the depth of the holes from which steam was escaping. By pacing a line parallel to the side and some fifty feet distant the length of the crater on June 28 was estimated at somewhat more than four hundred feet. This estimate is less than that given by some observers, but agrees closely with that made by Mr. Diller on June 20.[5]

EVIDENCES OF HEAT

Reports that the whole upper part of the mountain down to the 8500-foot level, approximately, had been snow-covered and that the snow had been melted by volcanic heat are entirely erroneous. Snow covered by the ash was still to be seen close to the crater and in considerable quantity on June 28. The new snow of June 23–25 was visible in patches on top of the ash,

[5] Science, Vol. XL, N. S., p. 50.

yet by digging through that and through the layer of ash below the old snow was found underneath. In fact, there was no evidence of heat on the mountain top other than the escaping steam. The ejected rocks seemed identical with the old lava rocks still in place on the mountain top. Naturally those ejected from a hundred or more feet below the surface would not bear indication of surface weathering, but there certainly was no rock found having the appearance of being recently fused.

LATER ERUPTIONS

The writer left Morgan Springs on June 29, there having been no eruption during his stay, unless minor ones took place at night. Heavy eruptions took place during the next three days and were briefly described as follows by Mr. Rushing in his report dated July 1:

June 30, 11:06 a.m., lasted until 12:14 a.m. Column ascended 2800 feet.

July 1, 5:30 a.m., lasted until 6:31 a.m. Very heavy eruption. Column ascended over 3000 feet. Heavy volumes of volcanic dust thrown out. No lava, flames, or earthquakes were noticed.

Many wild rumors of forest officers and private individuals being injured or lost are in circulation, but there is no foundation to them, although many people are taking serious chances by visiting the crater.

Since that time until the date that this paper was tranmitted for publication there have been reports of other outbursts, as may be seen in the list of eruptions appended.

LIST OF ERUPTIONS, MAY 30 TO JULY 15, 1914

The greater portion of this list was prepared at Mineral under the direction of Forest Supervisor Rushing, but as additions have been made to bring it up to a later date he should not be held responsible for inaccuracies. Reports of eruptions at night and in cloudy weather are naturally most open to doubt.

No.	Date	Time	Character of	Duration	Size
1	Sat., 5/30	5:00 p.m.	Heavy	10 min.	25 x 40
2	Mon., 6/1	8:00 a.m.	Heavier	15 min.	275 x 60 60 ft. deep
3	Tues., 6/2	9:30 a.m.	Very heavy	30 min.	
4	Mon., 6/8	4:30 p.m.	Heavier	40 min	
5	Tues., 6/9	10:30 a.m.	Heavy, steam darker	30 min.	
6	Fri., 6/12	3:45 p.m.	Heavy, steam very dark	50 min.	400 x 100
7	Sat., 6/13	6:00 a.m.	Ashes fell at Mineral, heavy	30 min.	
8	Sun., 6/14	6:00 a.m.	Unconfirmed, reported by Red Bluff	?	
9	Sun., 6/14	9:43 a.m.	Altitude smoke 2500 ft., heaviest yet	30 min.	
10	Sun., 6/14	6:45 p.m.	Medium	15 min.	450 x 125
11	Fri., 6/19	8:15 p.m.	Altitude smoke 2000 ft., medium	15 min.	600 x 150
12	Mon., 6/29	3:00 a.m.	New snow covered by layer of ash	?	
13	Tues., 6/30	11:06 a.m.	Heavy, series of slight eruptions followed first, alt. 2800 ft.	40 min.	
14	Wed., 7/1	5:30 a.m.	Heaviest yet, alt. smoke 5900 ft., as per calculations	50 min.	
15	Thur., 7/2	6:50 a.m.	Very heavy	30 min.	
16	Mon., 7/6	3:30 a.m.	Reported by Red Bluff, heavy, steam and smoke from entire length of crater	30 min.	
17	Sat., 7/11	6:35 a.m.	Light	30 min.	
18	Mon., 7/13	3:00 p.m.	Light	90 min.	
19	Tues., 7/14	6:00 a.m.	Light		
20	Wed., 7/15	12:05 p.m.	Heavy		

SUMMARY

Lassen Peak, an old volcanic cone in a region where a lava flow occurred some two hundred years ago, has exhibited true volcanic activity during the past six weeks. In the bowl of the much eroded old crater a series of steam explosions have opened a new vent, and from it stones have been thrown over an area more than one-half mile in diameter, and ejected volcanic ash has been wind-borne in sufficient quantities to make a perceptible deposit at a distance of fifteen to twenty miles. No freshly

molten lava has been seen and no heat has been noticeable, except that of the escaping steam. Sulphur fumes and slight sulphur deposits near the vent have been noticed by nearly all observers.

The source of the heat causing the explosions of steam is a matter of conjecture. It may of course be due to an ascending column of lava working its way up the old vent, but such suggestions are merely speculations, as would be any opinion as to the future activity of the volcano.

Transmitted July 16, 1914.

PLATE 32

Lassen Peak and Vicinity

The area shown is the central portion of the Lassen Peak sheet of the U. S. Geological Survey. The quadrangle was surveyed in 1882-84. As reproduced here the scale is practically four miles to the inch.

PLATE 33

Fig. 1. Lassen Peak from the southwest. This view, showing the upper fourth of the mountain, was taken from a peak about three miles distant and approximately 8000 feet in height. The two minor peaks at the top are the ends of two eroded ridges, the remnants of the walls of the ancient crater.

Fig. 2. Limit of falling ash not wind-borne. The viewpoint was at an elevation of about 8500 feet on the south slope of Lassen Peak. A slight fall of new snow partially obscures the ash. June 28, 1914.

PLATE 34

Fig. 1. The new crater as seen June 28, 1914, from the south wall of the old crater. Occasionally puffs of steam came from the right-hand end of the new vent. By pacing, the length of the crater was estimated to be approximately 400 feet.

Fig. 2. The fire lookout station of the U. S. Forest Service on June 26, 1914. The holes in the roof were probably made during the eruption of June 14. The house is built on a crag located at the right on the extension of the ridge showing in immediate foreground in the figure above.

PLATE 35

Fig. 1. The northwesterly end of the crater on June 28. Whenever the steam was blown aside, a crack was visible extending in the line of steam jets.

Fig. 2. The southeasterly end of the crater on June 28. The crack leading to the right (partially filled in) extends in the same direction as the general trend of the new crater. See also plate 34, figure 1. The elongated crater and the cracks suggest that the new vent may be an opening along a fault line.

PLATE 36

The Eruption of June 14, 1914

This series, showing four stages in the eruption beginning at 9:45 A.M., was obtained by Mr. B. F. Loomis, of Viola, from a point about six miles to the northwest at an elevation of nearly 5000 feet. The time interval represented by the entire plate is about fifteen minutes.

UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY

Vol. 1, No. 8, pp. 331-372, pls. 37-44 March 8, 1916

PHYSIOGRAPHIC FEATURES OF CACHE CREEK IN YOLO COUNTY

BY
DAVID M. DURST

CONTENTS

INTRODUCTION

The watershed of the Coast Ranges of California when considered as a unit is simple. A glance at a model or map of this California province reveals the striking fact that, like the Sierra Nevada Range, the Coast Range mountain system, notwithstand-

ing its irregular drainage pattern, has its water-parting near the eastern side, except in the vicinity of Clear Lake. The tributaries of this lake head well to the westward of the main crestline, and yet the outlet, Cache Creek, drains eastward into the Sacramento Valley. This is a recent modification if Clear Lake formerly poured its water into the Russian River, as was stated by Dr. Fairbanks,[1] although the most recent changes have been in the opposite direction, as has been pointed out by Professor Holway.[2, 3] Since the streams as far west as St. Helena Range pour their contents into Cache Creek, the volume of water passing down it is greater than that of any other stream which enters the Great Valley of California from the west. This factor must not be overlooked in the study of the development of the stream topography of the region under consideration. The paper will deal particularly with the physiographic relations of that part of Cache Creek which lies wholly in Yolo County. This includes about three-fifths of its length and consists of the lower and middle portions as far up as Fish Creek. The complexity of the geological structure and its direct bearing upon the physiographic forms will necessitate a description of the geology of the area which lies in close proximity to Cache Creek. It will also compel a consideration of some of the topographic features not directly controlled by the erosional forces of Cache Creek but which are of aid in helping to solve some of the more complicated problems. The only map of this region to the knowledge of the writer is the official county map,[4] which has been of great service. The U. S. G. S. topographic map has covered the Great Valley portion of the basin, but is of very little service in connection with the real problem. Former publications concerning this region are very few. Osmont[5] has very briefly described part of the geology. The water-supply paper[6] "Stream Measurements

1 Fairbanks, H. W., The Geography of California, p. 96.

2 Holway, R. S., The Russian River, Univ. Calif. Publ. Geog., vol. 1, p. 13, 1913.

3 Holway, R. S., Physiographic Changes Bearing on Faunal Relationships, Science, n. s., vol. 26, p. 382.

4 Ashley, P. N., Official Map of Yolo County.

5 Osmont, V. S., Geological Section of the Coast-Ranges North of Bay of San Francisco, Univ. Calif. Publ. Bull., Dept. Geol., vol. 4, p. 55, 1905.

6 U. S. Water Supply Paper, No. 298.

in the Sacramento River Basin'' and the ''Report of the State Water Commission of California for 1912''[7] give a brief description of Cache Creek from the standpoint of conservation of water for irrigation purposes.

GENERAL GEOGRAPHY

Cache Creek, the outlet of Clear Lake, is about seventy-five miles north of San Francisco. From the lake it flows in a general southeasterly direction through the counties of Lake, Colusa, and Yolo. The greater portion of its course is in Yolo County, and it runs through the entire county to its sink northeast of Woodland. The waters ultimately reach the Sacramento River by way of the sloughs leading out of the Yolo Basin. The Clear Lake Hydrographic Basin gathers the greater amount of rainfall. This upper part of the Cache Creek drainage basin comprises about 824 square miles, lying in the central part of Lake County east of the divide of St. Helena Range. It is somewhat rectangular in form, with Clear Lake occupying the center. The lake is about twenty-five miles long and its greatest width seven miles. The Clear Lake drainage basin is mountainous and rugged. The principal streams entering the lake are Scotts, Middle, Clover, and Kelsey creeks. From the lake, Cache Creek flows for five miles through an open country similar in topography to that bordering the lake.

The next twenty-five miles include the Cache Creek Cañon. The grade increases from 4.53 feet per mile for the first five miles from the lake to a maximum of 137.94 feet, with an average of about 35 feet per mile. The principal tributary enters Cache Creek in the cañon fourteen miles from the lake. It is fed by the winter rains and therefore its volume of water is not very large, except through its torrential period. This branch is called the North Fork of Cache Creek, and drains about 250 square miles in eastern Lake County. The only other tributary of importance is Bear Creek, also entering Cache Creek from the north and draining the southwestern part of Colusa County.

[7] Report of State Water Commission of California for 1912.

After emerging from the gorge of Cache Creek Cañon, the stream turning more to the south enters Capay Valley (pl. 38). Here it assumes a grade of 9.5 feet per mile. The valley is twenty miles long and varies in width from one mile near Rumsey to three miles near Cadenassa. To the west of the valley is the Rumsey Range of mountains, while to its east is the Capay Range. At Capay the creek enters the Great Valley of California. The remaining portion of the drainage area may be divided into the Hill District and the Sacramento Valley proper. The Hill District extends as far east as the low but striking east-facing front of the hills, west and northwest of Woodland. Through part of this region the creek meanders, having cut its course nearly to base-level. The lower portion of the stream in the floor of the Sacramento Valley has built up alluvial slopes bordering its former channels. At present the stream empties its contents into the Yolo Basin, since it has now no alluvial ridge competent to carry it across to the natural levee of the Sacramento River.

The mean annual precipitation ranges from seventeen inches in the Great Valley to over forty inches on some of the higher summits in Lake County. Consequently the greater volume of water passes through the entire length of Cache Creek, because of the heavier rainfall in the mountains of Lake County.

PHYSICAL AND GEOLOGICAL FEATURES

Because of the dependence of the stream system upon the geology of the region, I shall briefly enumerate some of the more interesting general geological features which bear upon the facts and help to solve the problems. As stated before, I shall consider only that portion of Cache Creek lying within the boundaries of Yolo County for detailed study. Topographically, this region extending from the western boundary of Yolo County to the Sacramento River owes its general features to its position in the Sacramento Valley and the Coast Range mountains. The minor details are due to the internal structure and erosional features, which divide the territory into four physiographic units, as

follows: (1) the Rumsey Range; (2) Capay Valley; (3) Capay Range; (4) the Hill District and the plain area of the Sacramento Valley (see map, pl. 37, for locations).

Rumsey Range

The Rumsey Range is a rugged mountain group and has a general trend of N 22° W, in accordance with the Coast Range system. It is the continuation of the mountains west of Winters seen so conspicuously from the Sacramento Valley. Rumsey Range is also the dominant feature west of Williams, where it is the first range bordering the Great Valley. The western boundary of Yolo County follows its crest for many miles until it is no longer the parting of the Putah Creek drainage from that of Cache Creek. The even skyline of the range, notched here and there by small streams as if cut by a knife, can undoubtedly be correlated with the Bellspring peneplain of the Klamath Mountains as described by Diller.[8]

> The Bellspring peneplain ends abruptly on the crest of the foothills along the western border of the Sacramento Valley plain in Colusa County. The bold front facing east has an altitude of nearly 2000 feet, and extends southward more or less continuously through Yolo County into Solano County. South of the deep gap cut in this front ridge by Putos Creek the crest rises from 2500 to 2900 feet.

The rocks forming the bulk of the range are of Cretaceous age, dipping in a northeasterly direction at an angle greater than 45°. They exhibit the same characteristics as the rocks elsewhere of this age in California, namely, an alternation of shale and sandstone. It is estimated by Osmont[9] that the Cretaceous section near Rumsey is five miles in thickness. This series consists of sandstone and shale. The sandstone is hard, fine grained, and yellowish in color. The strata are hardly over fifteen feet in thickness. The shale varies more in thickness than the sandstone, but on the whole the rhythm of sandstone and shale has made the bedding a characteristic feature. The sandstone is often massive, taking on a concretionary form in weath-

[8] Diller, The Topographic Development of the Klamath Mountains, Bull. 196, U. S. G. S., p. 20.

[9] Osmont, V. C., *loc. cit.*

ering. This seems to be more true of the upper member of the Cretaceous. Cache Creek breaks through the Rumsey Range northwest of Rumsey, exposing a magnificent section across the strike of the Cretaceous series. The creek is still at work cutting its way through the easterly dipping beds of Cretaceous age (pl. 40). This cañon carved out by Cache Creek is a very deep gorge. The bluish color of the shales and the two pillars of rocks on the wagon road give rise to the name Blue Gates so frequently used in this vicinity.

Capay Valley is probably the result of the down-folding of the Cretaceous and Tertiary beds modified by faulting and erosion. The width of the valley averages about two miles, while its length is twenty miles. The general trend of the valley is N 25° W to a point west of Cadenassa, where the valley leaves the fold of the syncline and takes an easterly direction The valley is narrow in its upper part, but widens as it continues southward.

On the west side of the valley are found Tertiary beds lapping upon the northeasterly dipping Cretaceous beds which form the Rumsey Range. On the east side of the valley are Tertiary beds underlain by the Cretaceous shales and sandstones dipping west at a fairly low angle. The Tertiary rocks of Capay Valley consist of a succession of clays, limestones, gravels, and conglomerates, which respond very readily to the agencies of weathering and erosion. In the northern portion of the valley the greater mass of the rocks of Tertiary age consists of gravel and clays, while in the southern part it consists of clays and limestones. This intergrading of the gravels into limestone toward the south presents some picture of the former shore conditions. Shallow water near shore in the north with deeper waters to the southeast made up the former geography of this region. It is difficult to obtain good exposures because of the alluvium covering the valley floor.

Capay Range

The Capay Range extends from the town of Capay in a general direction of N 28° W for about twenty miles, where it fades into the plains of the Sacramento Valley southwest of

Williams. The altitude varies from 800 to 1700 feet. The top of the range exhibits a comparatively even surface. When viewed and studied from Great Valley side it appears to be nothing more than a simple fold. But as one passes the axis of the anticline nothing startles one more than the very rapid descent into Capay Valley. A wagon or automobile can be driven almost anywhere on the top of the fold and to the very edge of the steep precipice, where there is almost a sheer drop to the west varying from 50 to 250 feet. The rupture of the earth's crust extending along the western slope of the anticline plays its role in the physiographic development of Cache Creek.

In the vicinity of Summit Valley no great displacement can be observed, as the fault seems to have split in this area. Northwest of Summit Valley the faulting becomes very marked and continues so until it becomes indistinct northeast of Rumsey. South of Summit Valley a fault is again a very conspicuous feature of the landscape and can be readily followed to the alluvium of Capay Valley west of the town bearing the name of Capay. The east-dipping strata of Cretaceous and late Tertiary age are well exposed along this line of breakage. Cache Creek has occupied part of this line of fracture near the Cranston farm. This will be referred to later.

All the strata west of this line of displacement dip to the west and pass beneath the alluvial sediments of Capay Valley, with one exception where the Cretaceous and Tertiary beds have been thrown into a fold southeast of the town of Guinda. This anticline is not parallel with the valley, but takes on a more westerly trend, so that part of the fold has been cut away by Cache Creek. If this line of folding continues, as is probably the case, it will pass just to the east of Guinda. The large faulted fold comprising the main ridge of the Capay Range (pl. 37) consists largely of Cretaceous rock with Tertiary and Quaternary formations occupying the minor place. The greater part of the Tertiary is found lying upon the Cretaceous on both sides of the fold.

The upper strata of the Cretaceous on the east side of the Capay Range having a northeasterly dip consist mostly of thin-bedded shales and sandstones. The uppermost sandstone is con-

cretionary. Local faulting in the shale and sandstone is a conspicuous feature along the eastern part of the range. The break between the Cretaceous and Tertiary is very marked in lithology. The Tertiary, as far as investigated by the writer, lies unconformably upon the Chico, having but a slight change in dip.

A cross-section of the strata taken in Murphy's Cañon between the upper Chico series and the Tertiary reveals the marked lithological change between the rocks of these two periods. This can be readily seen from the table.

Upper Tertiary	Gravels: Well water-worn and unconsolidated.
	Clay: Yellowish to bluish in color.
	Conglomerate: Pebbles about the size of the thumb.
	Clay
	Conglomerate
	Clay: Blue on top, yellow at the base, with increase of sand.
	Conglomerate: Fine pebbles.
Upper Chico	Sandstone: Coarse, with pebbles.
	Shale: Yellowish.
	Sandstone: Coarse.
	Shale: Blue, faulted in middle section.
	Sandstone: Fine in texture. The middle part of this thin-bedded sandstone is fossiliferous. The fossils are Ammonite and Dentalium.

The alternation of the sandstone and shale and the marked change in the texture of the rocks present some idea of the former shore conditions during the process of deposition. The shale members increases in thickness with greater rapidity than the sandstone. This rapid alternation did not stop at the close of the Cretaceous time, but continued well into Tertiary times. In the upper Chico series there is but one exception which breaks up the regular succession of shale and sandstones. This is in the form of a series of conglomerates about fifteen feet in thickness near the upper part of the Chico series. They are reddish in color, very firmly cemented, and contain a large number of fossils. The pebbles of the upper part of the conglomerate are small, while the lower part becomes distinctively coarse. It begins with small pebbles, alternates with coarse sandstone and

shale, and finishes with pebbles from the size of a pea to that of an egg. The conglomerate is very widely spread over the Capay Range, and, because of its distinctive character, it can be readily recognized, forming a basis for the correlation of structural geology. It was found in Murphy's Cañon; on the west-dipping rocks of Capay anticline, southeast of Guinda; in the east-dipping rocks of the Guinda anticline and in the west-dipping rocks of the same, and also as float material in Cache Creek, where it follows the fault east of the Cranston Ranch.

The fossils are exceptionally well preserved in the conglomerate, but perfect specimens are hard to obtain because of the firm cementation. The locality in Murphy's Cañon yielded the following fauna, which indicates without doubt that these beds are of Chico or upper Cretaceous age.

FAUNA[10]

Locality Two	*Locality Three*
Glycimeris veatchi (Gabb)	Ammonite
Nemodon vancouverensis (Meek)	Belemnite?
Ostrea sp.	Nemoden vancouverensis (Meek)
Nucula?	Dentalium cf. cooperi Gabb
Cinulia cf. obliqua Gabb	Perissolax breverostris Gabb
	Volutoderma californica Dall

The shale immediately above and between the strata yielded a few specimens which are of the same species.

The shale in the small valley on top of the Capay Range gave a fauna entirely different from the one in the conglomerate series. The shale outcrops here in great thickness and has been eroded very much faster than the sandstone farther east, forming a valley averaging two miles and a half in length and a quarter of a mile in width, called Summit Valley. This valley lies on the west side of the higher peaks of the Capay Range, and it is drained eastward by the north fork of Buckeye Creek. The fauna[11] of the shale as found in the valley is *Baculites* cf. *chicoensis* Gabb; ammonite; pelecypod; *Pholadomya,* n. sp.; and *Inoceramus* sp.

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10 Determined by Mr. Earl Packard of the University of California, to whom the writer is greatly indebted.

11 Determined by Mr. Earl Packard.

The surface feature of the large fault which breaks the fold of the Capay Range has already been referred to. The diastrophic movements of the two blocks are difficult to ascertain. Frequent landslides have made the task difficult because of the lack of good exposure. In many places the beds have been thrown into almost vertical positions due to slipping along this zone. One of the results of faulting is the bench extending along the greater part of the fracture. This is so well developed that it is used for a great part of the way as a wagon road. The movement from evidence found in the field was a downward thrust of the west block, this displacement causing beds southwest of Guinda to be thrown into a small fold, forming the Guinda anticline.

CAPAY VALLEY

That Capay Valley is a syncline and not solely the result of the normal processes of erosion can be recognized by field evidence. West of the Capay fault, the Tertiary and Cretaceous beds dip to the west. These in turn give rise to the Guinda anticline and then dip under Cache Creek and the alluvium of Capay Valley, forming a syncline. The beds north and south of the Guinda anticline pass directly under Cache Creek and are again found on the west side of the valley. The Guinda anticline is a few miles in length; the northern part is swept away by Cache Creek, while the southern part fades into the larger fold forming the Capay anticline. Where the smaller anticline fades into the larger it shows great complexity of structure. Here the fold is slightly overturned, seeming to indicate a westward pressure. The greatest width of the Guinda anticline is between three-fourths of a mile and one mile. The elevation surrounding this range of hills is at least 300 feet above the surrounding territory.

The fossils obtained from the well cemented conglomerate of the Guinda anticline are listed below.

FOSSILS FOUND IN GUINDA ANTICLINE[12]

Arca sp.	Glycimeris veatchi (Gabb)
Ostrea sp.	Dentalium sp.

Northwest of the Cranston Ranch near Cadenassa a conglomerate of Tertiary age dips to the west, its hardness causing a riffle in the creek. East of Cranston's residence Cretaceous beds dip to the west at low angles. In the hills north of Cadenassa and southeast of Brooks P. O. the Tertiary beds consist of limestones, clays, and conglomerates, having a westerly dip and pass under the alluvium of the valley. This valley is used by the railroad and is really the Capay Valley proper. These beds are pitched at a low angle, corresponding with those noted in the creek.

A section southeast of Rumsey reveals an interesting fact. The top stratum begins with limestone, dipping beneath the valley. This is followed by a succession of beds consisting of gravels and clays showing alternation of depositional conditions. These beds of Tertiary age have a westerly dip. Seven strata of gravel were counted, varying in thickness from five to twenty-five feet. The pebbles of the gravel beds are well water-worn, ranging in size from that of a pea to three and four inches in diameter. These gravels are fairly compact but not firmly cemented. Some beds have a bluish color, while others are so weathered that they have taken on a reddish cast. The clay is deep blue and alternates with the gravel. The blue cast of the gravels is due to the mingling of the blue clay and gravels. Both the gravels and clays are non-fossiliferous. These are without doubt of Tertiary age, because they rest upon the Cretaceous and have the same position with reference to the Cretaceous as those on the east side of the Capay Range.

The beds form a series not less than 300 feet in thickness and probably reach a maximum of over 500 feet. The tributary cañons that have been eroded into this series are the result of either one or both of two causes. Cache Creek at the present time is cutting into the east bank, which is composed of this soft material. Therefore as fast as the material is brought down by

[12] Determined by Mr. Earl Packard.

the small tributaries Cache Creek at the present time carries it away, except for the large boulders. This removes the deposit, so that the smaller streams can be more active. The other cause is probably overgrazing, as the hills have been cropped very close by pasturing sheep on them. This would be in accordance with views held that the rejuvenation found in recent years of many gullies in the Coast Range mountains is the result of overgrazing.

Deep, narrow cañons with flat gravelly bottoms are a characteristic feature. The great amount of material torn loose by the rain and other agencies of erosion cannot be handled under the present volume and grade of the tributary streams, so that there is aggrading of their stream beds. The perpendicular walls are the result of the blue clay underlying the more resistant gravels. The action of the raindrops and trickling waters have sculptured the nearly vertical walls into grotesque and fantastic shapes. Pinnacles and columns capped by small fragments of cemented gravel are not uncommon occurrences (see pl. 43, fig. 1). This sculpturing, aided by the blue and reddish color of the clays and gravels respectively, gives the walls a scenic beauty. A continuation of the gravel beds can be noted north of the Coast Ranges and northeast of Rumsey, where their position is almost horizontal.

THE HILL DISTRICT

The structural geology of the region east of the Capay Range, comprising the Hill District, is comparatively simple. This area is made up of Tertiary beds dipping eastward at a low angle. At Dunnigan, Zamora, and Yolo these lower beds pass under the alluvium of the Sacramento Valley, forming a part of the Great Valley syncline. The upper beds have been removed by erosion. The topography of the region is the result of erosion. The streams have carved many gulches and deep valleys into the once flat surface. The hills have become well rounded and are grouped to form long ridges, which are very much dissected by lateral streams, so that they are broken into knolls. These hills are flat-topped, with a north front steeper than that on the south. As one looks over the tops of them he is immediately struck by the fact that they seem to have about the same elevation, giving

the appearance of a former plain. The hills stop very suddenly west of the towns of Dunnigan, Zamora, and Yolo. No conclusive evidence of faulting has been found, even though from the U. S. G. S. map of the Dunnigan sheet and as seen from the railroad the eastern front resembles a fault scarp.[13]

This series of strata of Tertiary age lap upon the Chico rocks which form the fold of the Capay Range. Fragments of these beds were found on top of the fold, indicating that in part they extended over the fold and are coincident with the Tertiary gravels in the Capay Valley.

THE PROBABLE FORMER GEOLOGICAL HISTORY

The enormous thickness of the Cretaceous beds near Rumsey could have accumulated only by the slow subsidence of a trough. The rapid alternation of shale and sandstone gives some facts as to the history of deposition. The variation of the deeper and shallower water conditions was carried throughout the entire Cretaceous times. During the Tertiary epoch were deposited the gravels and clays which are now found resting upon the Chico beds. Then came probably the diastrophic movements which tilted the strata of Rumsey Range and at the same time threw the Capay Range into a fold. This fold was broken, giving rise to the Capay fault. The pressure seemingly came from the east and partly overturned the fold. This probably caused the buckling which formed the Guinda anticline. With the folding of the Capay Range, the Capay syncline came into existence. Meantime erosion reduced this region and possibly the entire Coast Range to approximately a peneplain condition (pl. 39, fig. 1).

As the Rumsey and Capay ranges were elevated, Cache Creek flowed down the Capay syncline, apparently cutting through the fold near Capay. The Capay syncline is not one of symmetry. The eastern side is steep, while the beds of the western side are gentler, due to the westward pressure in its forming. The waters of Cache Creek have worked their way to the eastern side of the valley. Cache Creek in its early history undoubtedly took up

[13] In a recent publication, Water Supply Paper 375-A, Mr. Kirk Bryan refers to this scarp and calls it the Hungry Hollow Fault.

its position near the eastern edge of the Capay syncline and intrenched itself in the soft Tertiary rocks. As erosion took place in the soft Tertiary beds or sediments the creek intrenched itself in the Tertiary beds, later cutting down into the upper Chico beds, which are very much harder. This kept it from migrating to its natural position near the center of the syncline. Cache Creek cut its way through these harder rocks as rapidly as the smaller streams, comprising Salt Creek and Brooks Creek with their tributaries, eroded the softer Tertiary strata of the upper part of the syncline, leaving the peculiar topography displayed in the region northeast of Cadenassa, where Cache Creek enters the hills. A factor instrumental in this result lies in the probable fact that Cache Creek found its way along the crushed zone of the fault, where it very readily removed the looser rock.

With the elevation of the Rumsey and Capay ranges, the beds on the western side of the Great Valley took on an easterly dip. The Tertiary beds were bent with the Cretaceous in the folding, and the streams took their normal courses down the gently east erly dipping beds which form the western part of the Great Valley syncline. So the streams of the Hill District started with an easterly direction and have retained that course to the present day, except for slight variations. It was the normal sequence of events. With the folding of the Capay Range the Hill District was slightly arched. The streams entrenched themselves and immediately set to work to reduce the area to base-level The soft sediments on top of the fold of the Capay Range were quickly tripped off and the gravels were deposited at lower levels, forming in all probability the last of the gravels whose remnants are to be found at the tops of the hills. These will be removed by future erosion. The stripping off of the Capay Range to a greater extent than the lower Hill District is due to its increased elevation and steeper slopes. It eroded the faster at the steeper parts of the fold. It is for these reasons that we find very little evidence of the Tertiary sediments on the slopes of the fold. When the gravels of the lower Tertiary beds were reached rapid erosion followed, so that where the Tertiary laps upon the Capay fold a notch is very noticeable, due to the gravel beds having been removed more rapidly than the overlying beds. This gives

the range the appearance of a bold front which one might from a distance characterize as faulting. Where Cache Creek traversed the hills it cut very much faster than the smaller streams because of its volume. With the aid of the smaller streams, Cache Creek has reduced the former hills almost to a plain, except for the area containing the small rolling hills west of the city of Woodland.

The field evidence is too meager to determine the cause for the seemingly bold front of the Hill District which borders the plains of Sacramento Valley west of Dunnigan, Zamora, and Yolo. Several theories may be put forth which would produce the above results. If the Hill District extended farther eastward at one time, it may have been cut away by the Sacramento River in its meandering. Faulting may also have produced the condition. Some evidence seems to bear out the supposition. It may also have been the result of a monoclinal fold with the uplift of the Capay Range. Further work needs to be done to determine the true cause.

The area between the hills and the Sacramento River has been modified by the recent meanderings of the river. Low wide ridges thrown out into the plains by the smaller streams in building up their beds as they entered the Sacramento Valley from the west are an important factor in irrigation and in their effect on the drainage of flood waters.

CACHE CREEK AND ITS RELATION TO TOPOGRAPHY

Cañon Through Rumsey Range

Fish Creek enters Cache Creek from the south and flows into it at right angles. It is the last tributary of any consequence before the above stream enters Capay Valley. This tributary has worked its way southward along an exposure of shale which is of considerable thickness. Other streams exhibit this same characteristic and form what Professor Davis terms subsequent streams. The lateral streams are controlled directly by the character of the rock and stratification.

At the confluence of Fish Creek and Cache Creek two terraces can readily be distinguished (pl. 41, fig. 2). Those on the right-hand side of the stream present the best features, still showing at the bend of Cache Creek, the former channel of the stream. These terraces, where they are undercut by the present creek, show very distinctly the bevelled surface which constituted the former bed of the creek. None of the terraces are very high and they do not form a very striking physiographic feature of the landscape.

From Fish Creek to the head of the valley near Rumsey, Cache Creek has cut through the Rumsey Range, which is composed of east-dipping sedimentary strata (pl. 44, fig. 1). How a creek could cut through so high a range is difficult to explain except on the basis of a slow uplift. This would make it an antecedent stream. That uplifts have occurred is borne out by the terraces so well displayed at the mouth of the gorge. How general this may have been is not known. The upturned strata very frequently form cascades, where the waters are whipped into foamy whiteness. The course of Cache Creek through the Rumsey Range is fairly straight; no streams of any size enter the creek until the Capay Valley is reached. Streams that do enter it possess all the youthful characteristics of the larger stream.

Northwest of Rumsey the gorge abruptly comes to an end and the stream enters the open valley of Capay. At the transition point are located five definite terraces. These will be considered under a separate topic. As Cache Creek enters the Capay Valley it takes up its position on the eastern side of the valley. Numerous fragments of terraces indicate a series of stream terraces formerly extending through the greater part of the valley. These terraces are plainly visible two miles north of Guinda. They are also suggested south of the same town. The town itself is partly situated upon the upper terraces and partly upon the middle one. The upper terrace at this point is about fifteen feet higher than the intermediate terrace.

The tributaries that enter the valley from the west have cut deep gorges across part of the series that make up the Rumsey Range. The incisions notch the even skyline of the former ero-

sional surface as if cut by a knife. In the valley the streams have entrenched themselves in the alluvium, cutting directly across the terraces on their route to join the main stream.

Superimposition in the Capay Valley

Cache Creek in upper Capay Valley shows some tendency toward meandering. East of Guinda it throws its waters against the Guinda anticline and is deflected slightly westward, only to return to its original position along the eastern side of the valley. Here it continues until near Brooks P. O., where it leaves the broad, open valley floor and enters a small valley to the eastward which soon narrows to a gorge. Above this the small valley is about a half mile wide and a mile and a half long. The valley plainly suggests its origin, namely, that of being carved out by the erosional force of Cache Creek. On the Cranston Ranch the creek takes an easterly course across the strata of Tertiary age and enters the hills in a large bend, coming out of them near its intersection with Salt Creek (see pls. 37 and 42). On its journey through the hills it forms a gorge, youthful in development but further advanced than the gorge of Cache Creek Cañon. The grade of the stream is noticeably increased and, at the point where it cuts across the west-dipping strata, rapids are formed. After the creek has reached the most northerly point of its bend, at the Capay fault it sharply turns to the south, following the zone of fracture until it reaches the open valley again. The highest hill between the portion of the creek thus incised in the slopes of Capay Range and the main valley is four hundred and ten feet. Other peaks range from fifty to four hundred feet above the present waters of the creek and extend from Brooks P. O. to a few miles above Capay.

The broken rows of hills referred to in the preceding paragraph forms an interesting feature that is apparent to any observer. Really beginning northwest of Surrey, the main Capay Valley cuts through them at a point west of Brooks P. O. The eastern front of this semicircular ridge is bold and regular, while the west and south sides are not. This is the result of lateral cutting by Cache Creek in the past. The hills are composed of Tertiary rock, except the higher ones east of the

In traveling from Tancred to Cadenassa via Brooks, one is struck by the fact that Cache Creek swings farther and farther to the left and enters a smaller valley which eventually forms the gorge, while to the right is a large, flat valley west of Brooks (see detail map, p. 348). This valley broadens out south of Brooks and assumes a more easterly direction. At its greatest extent the valley is about one and one-half miles wide and five miles long. This includes its area from the time Cache Creek leaves it until the stream again joins it west of Capay. The valley is very fertile and is dotted with large valley oaks. Farms located here and there all show signs of prosperity. The railroad and wagon road pass up this valley, avoiding the gorge of Cache Creek through the hills. The open valley is in conformity to the upper Capay Valley, namely, in the extended part of the syncline.

The part of Capay Valley not traversed by Cache Creek is drained by two minor streams, Brooks Creek and Salt Creek. Brooks Creek drains the upper part, while Salt Creek receives the run-off of the middle and lower portions. The former stream rises in the mountainous region of the Rumsey Range and flows eastward, thence northeast, passing west of Brooks Postoffice, and becomes tributary to Cache Creek before it enters the hills. The north fork of Salt Creek rises in the mountains southwest of Cadenassa and flows northward as if to become tributary to Brooks Creek, but upon entering the valley it flows directly across it. On reaching the hills it turns southeast and follows down the north side of the valley. It has entrenched itself on the south slope of the hills north of Cadenassa, and it even cuts across part of them. To the south lies the broad open valley at a lower level. This is out of harmony with normal conditions. Salt Creek becomes tributary to Cache Creek after the latter emerges from the hills. The difference in elevation between Brooks Creek and Salt Creek cannot be more than twenty-five feet, as it is hardly perceptible to the eye. That the divide is very low is shown in plate 42, figure 2.

The middle fork of Salt Creek, draining the southern area, is normal, as is also the south fork. The south fork has worked its way along the more easily eroded clays and gravels of Ter-

tiary age. With the aid of the creek that flows near Esparto, the south fork of Salt Creek has reduced the region, making another easy pass into Capay Valley.

Another instance of inharmonious stream drainage is found in the smaller streams south of Cranston's residence, which are directly tributary to the major stream at the place. These streams rise in flat ponds in the open Capay Valley, north of Cadenassa, and cut across the hills in deep, narrow ravines, entering Cache Creek before that stream enters the gorge on its journey through the hills (text-fig., p. 348). An open country extends from the shallow ponds, where the smaller streams rise to Salt Creek, and at high water part of the run-off undoubtedly goes into Salt Creek, because of the very low divide. That such streams, where only a few feet difference in elevation would throw their waters into Salt Creek, should cut across the hills, which are about 150 feet above the creek bed, is contrary to normal stream drainage.

When considering the region from Brooks to the confluence of Cache Creek it is noticed that the streams are out of harmony with the topography and can be explained only by superposition. When Capay Valley was folded the clay and gravels of Tertiary age were also folded. In the erosion period which followed Cache Creek finally took its position near the eastern edge of the syncline and not near the axis. As it cut down it encountered the harder Cretaceous rock. Brooks and Salt Creek became normal tributaries to it. These entrenched themselves as did Cache Creek. Their position was determined by the former surface. As these streams cut down, the smaller streams kept pace and cut away the soft clays and gravels of the upper Tertiary. In time the smaller streams cut away most of the middle of the Capay syncline, resulting in the broad valley followed by the railroad. But the larger tributaries and Cache Creek held their own, as did the smaller streams south of the Cranston residence, giving the present inharmonious stream drainage.

The Lower Creek

Cache Creek's course eastward from the junction with Salt Creek is across the strata of the Tertiary and Cretaceous beds

which make up the Capay Range. In this vicinity are located the Capay terraces, which will be discussed later. The creek comes out into the Sacramento Valley at Capay, but keeps its easterly course toward the Yolo basin. Here it broadens out, decreases in grade and assumes the characteristics of a mature stream. To the north of it lies a comparatively level area, locally known as Hungry Hollow, which has a gentle slope to the south. Stretching from its banks southward is the region of Esparto and Madison. The creek cuts across a ridge of low, well-rounded and dissected hills five miles northwest of Woodland. These hills have been reduced to rolling knolls by erosion and present all the characteristics of matured topography.

Field evidence indicates that in former times the hills extended to Capay, but have been reduced to a plain by the agencies of denudation, except for this narrow belt of hills. This belt of hills extends northward and becomes the flat-topped hills west of Dunnigan and Zamora, extending from those places to the Capay Range (pl. 39, fig. 1). They are made up of rocks of Tertiary date. The hills stretch south of Cache Creek for a short distance, fading out into the alluvium of the Sacramento Valley.

For more definite evidence that the hills probably extended to the Capay and Rumsey range we must look to the hills lying north of the creek. Here we find that the strata dip at a gentle angle to the east, passing under the alluvium of the Sacramento Valley. The greatest elevation of the Hill District is in a line drawn west of a point between Dunnigan and Britona. The initial slope was normally to the eastward. Because of these facts all the streams assume eastward directions from the Capay Range, with the exception of those in the southern part of Hungry Hollow. Those south of the line of highest elevation in the former uplift have valleys with steep north slopes and gentle south slopes due to the waters working against the south-plunging fold.

Bearing in mind the east-flowing conditions of the streams, let us look at Hungry Hollow. At the Bandy Ranch the hills pass into the south-sloping plains of Hungry Hollow. The south fork of Oat Creek flows through the Bandy Ranch, but instead of

flowing south it plunges into the high hills to the east, where it has cut a valley through them, as have other streams. At the Bandy Ranch the difference in elevation between the south fork of Oat Creek and the creek that flows past the Center District schoolhouse and empties its water into Cache Creek is not more than twenty feet. With only this difference in elevation, it seems unnatural for the waters of Oat Creek to find their way through the higher eastern elevation to empty their contents into the Colusa Basin near Zamora. Beside this evidence, we find that all the creeks from the Center School District to Capay wind their way eastward and upon reaching the hills turn south and empty their waters into Cache Creek. Keeping these facts in mind, we must admit that in order to restore original conditions we must picture this entire region as higher and probably hilly, and now reduced by erosion. If the smaller streams have advanced far enough in the cycle of erosion to reduce this area of Hungry Hollow to a gentle plain, it is not unreasonable to extend the former hill area to the present region of Cache Creek. This can easily be pictured, because we have hills to the north of Cache Creek and south of it at Capay, and also north and south of the creek, west of Woodland, while the intervening part is slightly rolling.

East of the hills, near Woodland, Cache Creek becomes an aggrading stream. During its past history it has built out ridges into basins. The largest of these and one of greatest industrial importance is the Knights Landing Ridge. While building up this channel the creek emptied its waters into the Sacramento River. Knights Landing Ridge, joining the natural levee of the Sacramento River, forms a depression known as the Colusa Basin. During winter rains the streams from the hills pour the excess of water into the basin, flooding many thousands of acres. This ridge was cut in 1914 for the purpose of draining the Colusa Basin and taking care of the flood waters. The lower basin into which the waters of Cache Creek now pour is called the Yolo Basin. The waters eventually reach the lower Sacramento by sloughs. The old ridges built by Cache Creek and similar streams have become of great economic importance to the farmer of this section. Although abandoned by the streams, yet when

wells are drilled in these former channels a good flow of water is usually obtained which can be utilized to a great advantage under the modern system of pumping for irrigation.

Buckeye Creek is another stream which has built out a very noticeable old channel and can be readily recognized at Hershey Station, which is on the boundary of Yolo and Colusa counties. At present Buckeye Creek leaves its old channel west of Hershey Station and takes a more directly eastern route to the Colusa Basin.

Stream Terraces

Stream terraces, as has been pointed out, are an important part in giving us some data as to the former conditions in the evolution of topographic forms. The clearness and the definiteness of the terraces distributed over various parts of this area make the study of these a very interesting one in view of the various uplifts of the Coast Range mountains in general.

RUMSEY TERRACES

Where Cache Creek emerges from Cache Creek Cañon five terraces can be definitely seen on the north side of the creek, one above the other in step formation. The preservation of these is due to the fact that the curve of the creek is a sharp one, so that the waters have been undercutting the south bank, while that of the north has been unmolested. The lowest terrace is small and not very far above the present flood waters of the creek. The second is the largest at this point, the third is only a small remnant of a much larger one, the fourth is second in size, and the fifth is small. These terraces are usually covered with heterogeneous material. Where a cross-section can be obtained it shows larger boulders near the surface, surrounded by finer gravels. These can be readily seen in the pictures. The uppermost terrace reaches an altitude of at least 150 feet above the present level of the creek. These terraces are shown in plate 41, figure 1.

From this point the terraces stretch down the valley in broad lines. The terrace on the south side of the creek conforms to the lowest in the north bank. Continuations of these terraces are conspicuous features of the landscape north, northeast and

east of Rumsey. All of the orchards northeast of the creek are situated upon old terraces. Here the roots of the trees can easily work their way through the porous gravels and sediments in search of food. Abundance of water is stored in these gravels, making them of great economic importance to the orchardist of this section. The railroad terminus at Rumsey is located upon one of these lower former stream levels. Practically all of the Capay Valley owes its present valley features to the terracing of Cache Creek, with the exception of the region around Cadenássa.

CAPAY TERRACES

The broad, flat-topped area north of Cache Creek and northwest of Capay immediately suggests to the eye a terraced surface. Above this prominent terrace is another remnant of a former position of the creek. Lower terraces, but of less consequence, are to be found on both sides of the creek. The height above the present level of the stream of these upper terraces seems to justify the theory that these must be the result of uplift, and not of a temporary base level due to difference in hardness of rock.

CACHE CREEK CAÑON TERRACES

The terraces at the bend of the creek at the junction of Fish Creek and Cache Creek are two in number. None of these compare in height with the uppermost of those either at Rumsey or at Capay. Their importance lies in their probable relation to a possible general uplift. The uppermost one of the north bank still shows the course of the former stream channel. Both the upper and lower terraces show the bevelled-off east-dipping strata of the Cretaceous. On top of the bevelled-off strata are stream deposits. The terraces are being undercut by the lateral erosion of the stream. These conditions can be seen in the picture, plate 41, figure 2.

A bevelled-off surface with a fill on top, not very far above the present waters of Cache Creek and located about midway between the Fish Creek and the mouth of the cañon, shows the effect of terracing. No terrace in this cañon under present conditions could be preserved for any length of time because of

the steep grade and narrowness of the cañon. Under such a state of affairs the upper terraces were quickly obliterated.

BIRD AND BUCKEYE CREEK TERRACES

The terraces of importance seen in Bird Creek Valley are three in number. The uppermost one is the largest and most conspicuous feature of the landscape. The second is very much smaller and about fifteen feet lower. The third is small and ten feet below the second.

Terracing is also found along Buckeye Creek. Here the terrace material consists not of large boulders, but of small gravel, stripped from the gravel beds of Tertiary Epoch. Although these terraces of the minor streams are of no real consequence in the problem, yet they act as a clock in checking off the uplifts in unison with the major stream. This would indicate that the movement which marks the terracing of the larger streams was quite general and may at some future date be correlated with that which caused the terraces of the San Benito[14] and Russian rivers.[15]

SUMMARY

In developing the facts for our conclusions upon the physiographic features of Cache Creek we must bear in mind that the geology of this region has not been worked out in detail. Also the lack of topographic maps makes it much more difficult to account for minor features, which in turn would throw much light upon the larger features.

Cache Creek Cañon is the direct result of the stream cutting through the upturned strata of an uplifted region, where the upward movement did not exceed the rate of cutting. It therefore must be termed an antecedent stream. Its early history was that of a normal stream having normal conditions. The youthfulness of the topography is the result of the stream being

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[14] Lawson, A. C., Post-Pliocene Diastrophism of the Coast of Southern California, Univ. Calif. Publ. Bull., Dept. Geol., vol. 1, no. 4, pp. 152–153, 1894.

[15] Holway, R. S., The Russian River, Univ. Calif. Publ. Geog., vol. 1, no. 1, p. 15, 1913.

unable as yet to reach a permanent base level. That the uplifting forces acted intermittently is borne out by the display of successive terraces at Fish Creek and at the terminus of the cañon.

Capay Valley is the resultant of two forces—diastrophic and erosional. The creek in recent geological times has migrated little from its original course. The postion of Cache Creek with reference to topography in its meander into the Capay Range east of Brooks P. O.; the unnatural drainage of the tributary cutting across the higher hills on the Cranston Ranch; and the entrenchment of Salt Creek in the southern slope of Capay Valley, rather than in the floor of the valley, indicate that a former erosional surface existed which did not conform to the present topography. These irregularities are undoubtedly accounted for by superimposition. The valley in the vicinity of Cadenassa is not directly due to Cache Creek, but to the erosional forces of its tributaries. These smaller streams cut away the weaker gravels and clays at a rate about equal to that of the major streams in the more resistant beds in the hills.

The lower creek is a normal stream. With the folding of the Capay Range, or the depression of the Great Valley, the district comprising the lower creek was tilted and the streams intrenched themselves on the initial slope. This is borne out by the stream topography of the hill section. The streams assume and maintain an easterly direction, cutting across the hills. The only exception is in Hungry Hollow, where the streams have reduced the region to a plain. Here the creeks still maintain an easterly course until the eastern part of that hollow is reached, whence they flow south into Cache Creek.

Transmitted April 22, 1915.

PLATE 37

The outline of the map was taken largely from the official county map. The plate shows the important drainage systems. The location of each of the photographs reproduced in the following plates is indicated on the map by an index letter and arrow showing the direction in which the camera pointed.

PLATE 38

Index arrow 1, on plate 37. A view of Capay Valley from a point east of Guinda, looking northwest. The notch on the left shows the cañon through which Cache Creek flows before entering Capay Valley

PLATE 39

Fig. 1. Index arrow 34, on plate 37. A view of the flat-topped hills of the plateau west of Dunnigan. It shows the dissection of a former plain.

Fig. 2. Index arrow 24 on plate 37. A section of the Capay Range showing the fault scarp. The fault extends along the western side of the range.

PLATE 40

Fig. 1. Index arrow 6 on plate 37. A photograph of Cache Creek in the cañon northwest of Rumsey. The gorge has been carved out of the Cretaceous beds.

Fig. 2. Index arrow 5 on plate 37. A close view of the nearly vertical Cretaceous strata in Cache Creek Cañon. These beds are of great thickness.

PLATE 41

Fig. 1. Index arrow 9 on plate 37. Stream terraces near Rumsey at the mouth of Cache Creek Cañon. Five in number exist here but not all can be seen in the photograph.

Fig. 2. Index arrow 4 on plate 37. Beveled strata of a low terrace in Cache Creek Cañon. The Cretaceous strata dip at a high angle. The stream deposits lie on top of the beveled surface.

PLATE 42

Fig. 1. Index arrow 20 on plate 37. Superimposed portion of Cache Creek. The creek leaves the main valley which can be seen beyond the hill inclosed in the bend of the creek and cuts across part of the Capay Range.

Fig. 2. Index arrow 16 on plate 37. A portion of Capay Valley not eroded by Cache Creek but by the tributary streams. The low divide between Brook's Creek and Salt Creek is shown in the center of the picture.

PLATE 43

Fig. 1. Index arrow 28 on plate 37. Rapid erosion in the gravels and blue clay southeast of Rumsey. These beds are of late Tertiary age.

Fig. 2. Index arrow 30 on plate 37. A view showing the west-dipping beds of late Tertiary time. These are being cut away by Cache Creek.

PLATE 44

Fig. 1. Index arrow 8 on plate 37. East-dipping Cretaceous beds at the mouth of Cache Creek Cañon near Rumsey. These beds are enormously thick in this vicinity.

Fig. 2. Index arrow 31 on plate 37. East-dipping Cretaceous strata of the Guinda Anticline. A few hundred yards to the west of this photograph the beds dip to the west. The stream has cut across the fold.

UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY
Vol. 1, No. 9, pp. 373-439, pls. 45-55, 10 text figs. April 10, 1916

REPORT
OF THE
METEOROLOGICAL STATION AT BERKELEY, CALIFORNIA
FOR THE
YEAR ENDING JUNE 30, 1914

BY
WILLIAM GARDNER REED

CONTENTS

I. STATION REPORT

INTRODUCTION

The Meteorological Station, maintained by the University of California at Berkeley, was carried on under the direction of the Department of Geography during the year ending June 30, 1914. This is the second year of the control of the station by the department and this report is the second annual report which has been issued under the present direction. The station was established under the direction of Professor Frank Soulé, when the Students' Observatory (Berkeley Astronomical Department) was founded in 1886. The meteorological record kept by the University dates from October 16, 1886, without a break. In conformity with the practice adopted when the first five-year synopsis was published in 1892, that portion of the record before July 1, 1887, has been rejected; this practice permits the published record to conform to the administrative year of the University, which is also the most convenient annual unit for the study of the meteorological phenomena at Berkeley, especially the precipitation, which is under subtropical control, having winter cyclonic rains, forming a rainy season beginning in the fall and continuing to the next spring. This rainfall regime makes it almost necessary to separate the annual units at some time during the dry summer rather than at the beginning of the calendar year.

Although the Berkeley Astronomical Department is no longer charged with the maintenance of the meteorological work at Berkeley, the station has continued under obligations to the Director of the Students' Observatory, Professor A. O. Leuschner, for advice and courtesies too numerous to mention in detail. For many years the interest and assistance of Professor Alexander G. McAdie, Section Director of the United States Weather Bureau at San Francisco, was of the utmost importance to the work of the station; with his removal from San Francisco to become Director of the Blue Hill Meteorological Observatory early in September, 1913, the station suffered a loss, although his friendly interest still is of great value. The officials of the

United States Weather Bureau both in California and at the Central Office in Washington, particularly Mr. George H. Willson, District Forecaster at San Francisco, have always been willing to furnish assistance and advice. To the Department of Civil Engineering, especially Professors Hyde and Griswold, the station is indebted for rates of rainfall at Berkeley and for other courtesies.

Instruments and Exposures, 1913–1914

No change in the equipment or the routine of the station was made during the year. Temperature readings made from Green thermometers of the Weather Bureau pattern exposed in a cooperative observer's shelter, which is the property of the Weather Bureau, have been regarded as the air temperatures at Berkeley, although the observation of the instruments in the window shelter described on page 248 of the report of the station for the year ending June 30, 1913, have been continued. A comparative study of the results from the two exposures is in progress, but the results are not regarded as sufficient for publication as yet. A record of the constants of the station and the changes which have been made since the station was established is given in Table I in metric units and in Table I*a* in English units.

TABLE I

Changes in the Constants of the Meteorological Station at Berkeley, California

Date	ϕ	λ	H Meters	H_b Meters	h_t Meters	h_r Meters
October 16, 1886	+37° 52′	122° 16′ W	104.2	96.6	2.1	6.4
September, 1892	+37° 52′	122° 16′ W	96.3	96.6	2.1	0.3
October 1, 1899	+37° 52′	122° 16′ W	100.6	96.6	2.1	4.6
July 1, 1912	+37° 52′	122° 16′ W	100.6	98.0	1.5	4.6
July 1, 1913, to June 30, 1914	+37° 52′	122° 16′ W	100.6	98.0	1.5	4.6

The International Symbols are as follows:
ϕ Latitude of the station.
λ Longitude from Greenwich of the station.
H Altitude of the station (rim of the rain-gage) above sea-level.
H_b Altitude of the barometer cistern above sea-level.
h_t Height of the thermometers above the ground.
h_r Height of the rain-gage above the ground.

TABLE I*a*

Date	Latitude	Longitude	H Feet	H_b Feet	h_t Feet	h_r Feet
October 16, 1886	37° 52′ N	122° 16′ W	336	317	7	21
September, 1892	37° 52′ N	122° 16′ W	315	317	7	1
October 1, 1899	37° 52′ N	122° 16′ W	330	317	7	15
July 1, 1912	37° 52′ N	122° 16′ W	330	322	5	15

No new equipment was added during the year, except a number of spare instruments to insure a continuous record in the event of breakage. Besides the instruments in service at the station for the daily observations there are now available spare maximum, minimum, and exposed thermometers; a mercurial barometer which was used in measuring air pressure from 1886 to 1912 is still exposed at the Students' Observatory; the danger of the loss of an observation because of the failure of an instrument is therefore very slight. At the beginning of the year the number of terrestrial radiation thermometers was increased to four, so that studies of the frost conditions on the campus and elsewhere might be carried on. During the year two of these thermometers were stolen while exposed.

The instrumental equipment in service at the station during the year was as follows:

Maximum and minimum thermometers, United States Weather Bureau pattern (two exposures).

Wet-and-dry-bulb thermometers, mounted as stationary psychrometers (two exposures).

Richard thermograph, weekly record, standard size.

Richard hygrograph, weekly record, standard size.

Mercurial barometer, Fortin cistern, United States Weather Bureau pattern (Green), mounted in Weather Bureau barometer box.

Aneroid barograph, weekly record, standard size (Short and Mason).

Eight-inch rain gage, United States Weather Bureau pattern.

Terrestrial radiation thermometers (Casella) in various positions as the convenience of frost studies demanded.

The exposures are the same as during the previous year. The barometer and barograph exposure is in the Geography Laboratory in the southwesterly corner of the ground floor of Bacon

Hall (see plate 45); the elevation of the cistern of the mercurial barometer is 98.04 meters (321.65 feet) above sea-level.[1] The cistern is about 0.9 meter above the floor, which is the ground level. The thermometers, thermograph, and hygrograph are exposed in the shelter which is fully described on page 250 of the

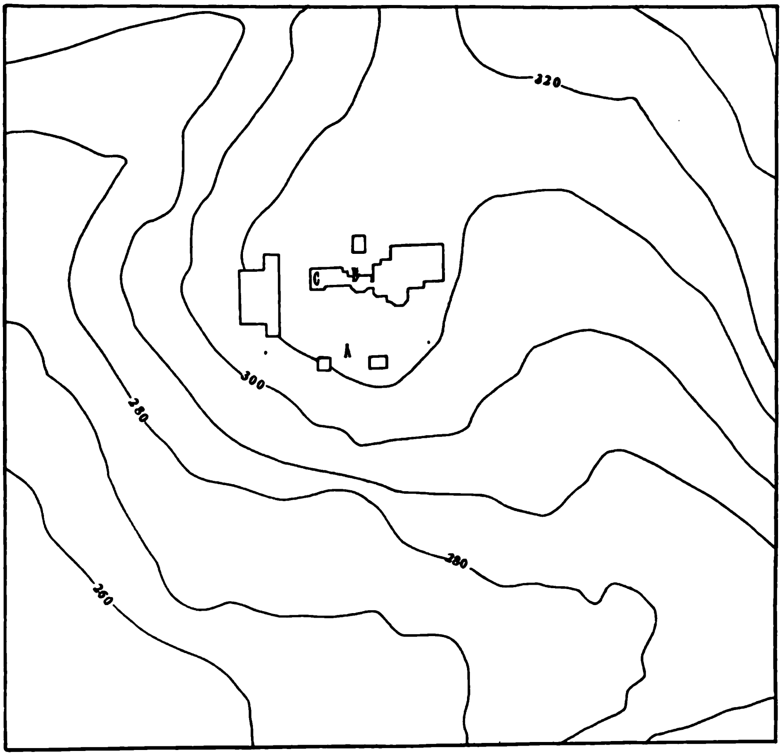

Fig. 1. Map of a portion of the Campus of the University of California, Berkeley, showing the location of the meteorological instruments at the Students' Observatory. Scale about 1:2200, contour interval 10 feet, 3 meters. From map by George B. Sturgeon, 1908. A, United States Weather Bureau, Co-operative Observer's Shelter, containing wet and dry, and maximum and minimum thermometers, thermograph, and hygrograph. B, window shelter from which readings were made previous to July 1, 1912, containing wet and dry, and maximum and minimum thermometers. C, location of rain-gage, on roof of building about 4.6 meters, 15 feet above the ground.

[1] For a complete description of the elevation see the Report of the Station for the year ending June 30, 1913, p. 250, Univ. Calif. Publ. Geog., vol. 1, no. 6 (1914).

Report for 1912–13 (see pl. 46, fig. 1). Temperatures at the surface of the ground taken irregularly on clear nights during the winter indicate that the line of air drainage, noted as suspected in the report, surely exists, so that the recorded minima are by no means the lowest temperatures reached on the campus. It is not improbable, however, that the recorded temperatures are fairly representative.

The location of the thermometers and rain-gage with reference to the local topography is shown by figure 1, which is reprinted from the report for the previous year. A discussion of the conditions of exposure and photographs of the shelter and rain-gage will be found in that report. The meteorological aspects of the exposures are also considered on the later pages of the present report.

The thermometer shelter is not as large as it should be to protect the instruments properly and to give them the necessary room. It has not been possible to use the Weather Bureau whirling psychrometer apparatus, owing to lack of room. The present location is regarded as temporary, as the permanent building plan contemplates other use of this site, and therefore it has been deemed inadvisable to build an adequate shelter until some assurance of the permanent location can be obtained. Plate 46, figure 2, shows the condition of the shelter.

The exposure of the rain-gage has not been changed since the preceding year. This is the roof exposure at C in figure 1 at the western end of the main observatory building. The elevation is about 4.5 meters (15 feet) above the ground on a flat roof which has an area of 25 square meters (275 square feet). There is a roof immediately to the east of this which has its ridge 1.2 meters (4 feet) above the middle of the roof on which the gage is exposed, but the edges of both roofs are at the same height. The sheltering effect of the ridge and of the surrounding trees tend to decrease the wind velocity and give truer rainfall measurements. There is no shelter within a distance equal to more than its height from the gage. But, as has been noted before, a proper exposure of the rain-gage cannot be obtained on a roof and a ground exposure should be obtained as soon as practicable. Unfortunately circumstances beyond the control of the

temperatures were obtained on most of the clear nights during the winter months from several places on the campus; these furnish the first data for the study of the distribution of frost on the campus. This work is, however, largely experimental in character. For each month in which the tipping-bucket gage was in operation maximum rainfall rates have been furnished by the Department of Civil Engineering.

During the year the work of the station has been under the immediate direction of the writer. The program of observations, the computing, and the publication of results have been under his personal supervision. The actual observations were made by the following observers during the periods stated:

July 1 to December 25, F. A. Shaeffer.

December 25 to December 29, S. B. Nicholson.

December 30 to May 9, F. A. Shaeffer.

May 9 to June 30, J. E. Krueger.

Single observations have been made from time to time by various observers, but the work has been carried on under the direction of the writer and all questions involving station policy and method of observation and computing have been referred to him. For the most part the suggestions of the International Meteorological Committee and the regulations of the United States Weather Bureau have been followed.

REPORTS AND PUBLICATIONS, 1913–1914

The regular form (No. 1009—Met'l) of co-operative observer's report has been prepared and sent to the office of the United States Weather Bureau at San Francisco at the end of each month. The report contains the following items: daily maximum and minimum temperatures, temperature ranges, amount and duration of precipitation, prevailing wind direction and general weather of each day, and miscellaneous meteorological phenomena. Printed summaries of the data collected by the station have been issued as follows:

Monthly Meteorological Synopsis of Berkeley, 2nd series, vol. 2, no. 1, for July, 1913, to no. 12 for June, 1914, Berkeley, 1913–14.

Monthly and Annual Meteorological Summary of Berkeley, in University of California Chronicle, vol. 16, pp. 105–106, Berkeley, 1914.

Monthly and Seasonal Meteorological Summary of Berkeley, in University of California Chronicle, vol. 16, pp. 311–312, Berkeley, 1914.

Twenty-five Year Synopsis of Meteorological Observations Made at Berkeley from July 1, 1887, to June 30, 1912, by Armin O. Leuschner, Univ. Calif. Publ. Geog., vol. 1, no. 5 (1914), Berkeley.

Report of the Meteorological Station at Berkeley, California, for the year ending June 30, 1913, by William Gardner Reed, Univ. Calif. Publ. Geog., vol. 1, no. 6 (1914), Berkeley.

In briefer form, Monthly Weather Review, vol. 42, pp. 164–166, Washington, 1914.

OTHER STUDIES

In addition to the routine work of the station, the following studies have received attention:

1. Frost conditions in Berkeley.
2. Temperature comparison between the campus and the Berkeley High School building.
3. Hydrographic survey of Strawberry Creek.

The first of these studies has been carried on during the year by the writer in a more or less casual manner, although the observations are accumulating for future use. The second is the result of the co-operation of the Berkeley High School, especially Mr. G. C. Barton, with the Department of Geography of the University. The hydrographic survey was carried on during the year as thesis work in the College of Civil Engineering, although the writer assisted in the meteorological aspects of the problem.

Frost Studies

During the year a number of terrestrial radiation temperatures were obtained from Casella grass minimum thermometers on certain clear nights. The thermometers were exposed in general when the sky was clear, or nearly so, at the evening observation hour when it seemed likely that freezing temperatures would be reached. The results do not yet indicate anything of importance, as the data are much too scanty. The original plan was to expose the thermometers at a number of places on the campus to determine the air-drainage lines, as well as the differences existing between air temperatures and surface temperatures in the same vicinity. The theft of the thermometers, however, rendered this impossible. Thermometers exposed near the

shelter and in the Botanic Garden (A in fig. 2) showed clearly that surface temperatures were usually five degrees or more (Absolute) below the air temperatures on clear nights. The lower temperatures at the surface in the Botanic Garden indicate that this represents a line of air drainage. In all cases when frost was observed, one or more of the grass minimum thermometers registered below 273° A (32° F), although in most cases the air temperature was above the melting point of ice. The study will be continued in the future as the opportunity offers.

TEMPERATURE COMPARISON

The installation of an instrument shelter by the Berkeley High School on the roof of the High School Building, on the flat land about a kilometer (half a mile) from the campus, has afforded an opportunity to compare temperatures from this part of Berkeley with those of the University campus. It is unfortunate that the exposures are not strictly comparable, but it is hoped that there will be results of the study which are significant. Summaries of the temperatures at the High School have been published in the *Meteorological Synopsis of Berkeley.*

HYDROGRAPHIC SURVEY OF STRAWBERRY CREEK

The water resources of Strawberry Creek have been of interest to the University because of the possibility of the development of this source of supply for use on the campus. During the winter of 1913–1914 an intensive study of the drainage area was undertaken as a thesis subject by Mr. H. M. Loy of the Senior Class in the College of Civil Engineering under the direction of Professor Charles Gilman Hyde. The meteorological station cooperated in this survey as far as the study concerned the meteorology of the region. Five rain-gages were exposed on the drainage area during the greater part of the winter in the attempt to determine accurately the amount of precipitation upon which the flow of the stream depended. The work with the rain-gages was done in connection with the recording weir maintained by the sanitary engineer of the University. The gages were of the standard United States Weather Bureau pattern, the diameter

The most important result of the study from a meteorological point of view seems to be that the questions of exposure of rain-gages must be much more thoroughly examined before it is safe to make a definite statement in regard to the rainfall of the drainage area of Strawberry Creek. The work is being carried on during the year 1914–1915 by Mr. M. K. White of the College of Civil Engineering with an increased number of rain-gages and the advantage of the experience gained during the past year. It is hoped that the survey may be continued until the actual conditions of the rainfall of the area and its relation to the flow of the stream may be fully known. The results of the study of the past year as far as they seem significant have been published in the *Monthly Weather Review,* volume 43, Washington, 1915.

II. BERKELEY METEOROLOGY, 1913–1914

Introduction

The monthly and seasonal summary of the meterological record kept at Berkeley during the year ending June 30, 1914, is presented in Table II, on pages 388 to 393. This table includes the same elements as the annual report for the year ending June 30, 1913, with in addition the number of days with thunderstorms and the number of days with hail. The addition of these data seemed desirable because of the fact that there was an unusual occurrence of both these elements. The table includes the elements suggested by the International Meteorological Committee together with additional statements which have seemed from the experience of the station to be of interest for such a report as the present.

The use of the CGS system of rational meteorological units has been continued for the reasons stated in the previous report;[2]

[2] The meteorological units used in this report are defined as follows:

Bar, a pressure equal to an accelerating force of one megadyne (1,000,000 dynes) per square centimeter.

Millibar, a pressure equal to one-thousandth of a bar, that is, one kilodyne (1000 dynes) per square centimeter.

Dyne, a force which acting for one second will impart to a mass of one gram a velocity of one centimeter per second.

Absolute temperature, the number of degrees above absolute zero in units whose length is one one-hundredth of the difference between the

cisco Bay is shown by plate 31, in the report for the year preceding.[4] The campus is located on the inner or eastern edge of the coastal plain which forms the eastern shore of San Francisco Bay. The distance from the water's edge to the instruments is about four kilometers (two and a half miles), and the elevation of this part of the campus is about 95 meters (310 feet). The slope is gentle and nearly uniform from the campus to San Francisco Bay, but immediately east of the campus the Berkeley Hills rise to elevations of over 300 meters (1000 feet) in less

Fig. 2

than two kilometers (a mile and a quarter). The Golden Gate is about twenty kilometers (twelve miles) west-southwest from the station, and the Pacific Ocean is about two kilometers farther to the west.

The local topographic features of the campus and the general locations of the various meteorological instruments are shown by figure 2, which is drawn from a plan made under the direction of the Supervising Architect by Mr. George B. Sturgeon. The thermometers, thermograph, hygrograph, and standard rain-gage have been exposed at the Students' Observatory (*O* in fig. 2); the exact locations of the different thermometers is better shown

[4] Univ. Calif. Publ. Geog., vol. 1, no. 6, 1914.

TABLE II—ABSOLUTE (CGS) UNITS

Summary of Observations at Berkeley, California, for the Year Ending June 30, 1914

Latitude +37° 52′. Longitude 122° 16′ west from Greenwich. Height of barometer cistern above sea, 98.0 meters
Height of thermometers above ground, 1.5 meters. Height of rain-gage above ground, 4.6 meters
Observations at 8^{hrs} and 20^{hrs} Mean Civil Time of the 120th Meridian (16^{hrs} and 4^{hrs} Greenwich Mean Civil Time)

Atmospheric Pressure. Sea-level equivalents in millibars

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
Mean air pressure[1]	1016.0	1015.2	1015.6	1016.7	1017.6	1019.2	1017.8	1019.5	1018.9	1017.8	1016.1	1015.0	1017.2
Maximum air pressure[2]	1021.0	1021.3	1020.6	1024.0	1027.1	1027.1	1033.8	1031.1	1028.4	1025.0	1022.0	1020.6	1033.8
Date	31	5	4	18	22	5	29	26	4	16	10	25	Jan. 29
Hour (Civil time, 120th meridian)	11	11	10	10	11	8	9	10	9	8	22	8	9
Minimum air pressure[2]	1006.7	1007.4	996.6	1005.7	992.2	1007.8	998.9	996.6	1007.1	1003.3	1010.5	1006.4	992.2
Date	11	30	18	1	18	22	17	20	29	21	31	6	Nov. 18
Hour (Civil time, 120th meridian)	20	18	17	18	13	1	18	15	3	5	18	20	13

Air Temperature (in Absolute Degrees)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
Mean air temperature[3]	290.6	291.5	292.3	290.2	285.4	282.6	283.1	284.6	287.7	287.5	287.3	287.8	287.6
Mean air temperature at 8^{hrs}	288.7	289.3	289.6	286.6	283.3	280.2	281.2	281.2	284.5	286.2	285.7	286.5	285.2
Mean air temperature at 20^{hrs}	288.3	288.9	289.2	287.3	284.4	281.7	282.3	282.2	285.5	285.3	285.2	285.8	285.5
Mean maximum temperature[4]	296.1	296.9	298.7	296.7	288.9	286.4	286.7	289.4	293.2	292.8	291.8	292.8	292.5
Mean minimum temperature[5]	285.1	286.1	285.9	283.6	281.8	278.9	279.5	279.9	282.2	282.2	282.8	282.7	282.6
Highest daily mean[3]	298.6	296.3	303.4	298.0	290.4	287.4	287.3	288.3	296.7	293.7	290.8	294.7	303.4
Date	11	6	16	19	7	11	1	15	17	18	11	27	Sept. 16
Lowest daily mean[3]	287.7	289.2	287.8	286.1	282.6	278.6	282.3	281.1	282.4	284.9	284.4	283.4	278.6
Date	18	25	28	24	21	19	15	22	29	22	18	6	Dec. 19
Maximum temperature[4]	308.0	306.2	313.8	308.2	296.9	292.1	293.0	294.4	303.6	302.6	297.3	303.4	313.8
Date	11	6	16	1	7	1	4	28	17, 18	18	11	27	Sept. 16
Minimum temperature[5]	282.4	283.8	283.2	280.4	277.4	275.2	275.2	275.9	276.5	279.6	280.4	280.2	275.2
Date	14	14	29	27	24	15	9	6, 7	27	24, 28	6	9	Dec. 15 Jan. 9

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
Monthly range	25.6	22.4	30.6	27.8	19.5	16.9	17.8	18.5	26.7	23.0	16.9	23.2	22.4
Mean daily range	11.0	10.8	12.8	13.1	7.1	7.5	7.2	9.5	11.0	10.6	9.0	10.1	10.0
Maximum daily range	19.0	19.8	23.3	21.4	12.8	13.1	12.0	14.0	16.4	17.8	13.9	17.4	23.3
Date	5	6	15	1	7	9	4	7	16	18	29	27	Sept. 15
Minimum daily range	6.0	6.1	7.1	5.8	1.8	2.1	1.7	3.5	3.7	4.9	3.6	2.7	1.7
Date	22	13	13	3	1	13	23	18	22	8	14	19	Jan. 23
Mean change from day to day	1.6	1.4	2.1	2.2	1.2	1.8	1.4	1.0	1.7	1.5	1.5	1.6	1.6

Moisture

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
Mean dew point at 8^{hrs}, °A	285	286	285	281	281	279	280	280	282	283	284	284	282
Mean dew point at 20^{hrs}, °A	285	286	285	282	282	281	281	281	282	283	284	284	283
Mean vapor pressure at 8^{hrs}, mb.	14.2	15.2	13.9	11.1	11.3	9.4	10.2	9.8	10.8	12.3	13.0	13.5	12.1
Mean vapor pressure at 20^{hrs}, mb.	14.0	15.2	13.8	11.3	11.8	10.0	14.1	10.9	11.7	12.3	13.0	13.4	12.6
Mean relative humidity at 8^{hrs}, %	81	82	76	75	93	92	95	89	82	82	92	88	86
Mean relative humidity at 20^{hrs}, %	82	86	77	72	88	91	96	85	82	87	93	91	86
Mean cloudiness at 8^{hrs}	.5	.6	.5	.4	.7	.6	.6	.4	.5	.6	.6	.7	.6
Mean cloudiness at 20^{hrs}	.4	.4	.3	.3	.5	.5	.5	.3	.4	.5	.6	.5	.4
Total precipitation, all kinds, mm.[6]	4.8	0.8	·	9.1	149.4	177.3	323.6	101.1	25.2	33.8	15.8	12.2	858.1
Max. precipitation in 24 hrs., mm.[6]	2.5	0.8	·	9.1	35.6	40.1	57.9	45.5	23.9	14.7	5.3	8.4	57.9
Date[7]	23	27	....	31	18	30	12	20	29	4	7	6	Jan. 12

[1] Reduced to a true 24-hour mean by corrections furnished by the United States Weather Bureau.

[2] From barograph corrected.

[3] $\frac{1}{2}$ (maximum + minimum).

[4] From mercurial maximum thermometer, United States Weather Bureau pattern.

[5] From alcohol minimum thermometer, United States Weather Bureau pattern.

[6] Includes rain, dew, and fog. In accordance with the recommendation of the International Meteorological Committee, absence of precipitation is indicated by a dot (·).

[7] Amounts to 20^{hrs} mean civil time (120th meridian) of the date indicated.

TABLE IIa—ENGLISH UNITS

SUMMARY OF OBSERVATIONS AT BERKELEY, CALIFORNIA, FOR THE YEAR ENDING JUNE 30, 1913

North Latitude 37° 52′. Longitude west from Greenwich 122° 16′. Height of barometer cistern above sea, 321 feet
Height of thermometers above ground, 5 feet. Height of rain-gage above ground, 15 feet
Observations at 8 A.M. and 8 P.M. Pacific Standard (120th Meridian) time

Atmospheric Pressure (in Inches of Mercury). Reduced to standard gravity and sea-level

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
Mean air pressure[1]	30.00	29.98	29.99	30.02	30.05	30.10	30.06	30.11	30.09	30.06	30.01	29.98	30.04
Maximum air pressure[2]	30.15	30.16	30.14	30.24	30.33	30.33	30.53	30.45	30.37	30.27	30.18	30.14	30.53
Date	31	5	4	18	22	5	29	26	4	16	10	25	Jan. 29
Hour (Pacific Time)	11 A.M.	11 A.M.	10 A.M.	10 A.M.	11 A.M.	8 A.M.	9 A.M.	10 A.M.	9 A.M.	8 A.M.	10 P.M.	8 A.M.	9 A.M.
Minimum air pressure[2]	29.73	29.75	29.43	29.70	29.30	29.76	29.50	29.43	29.74	29.63	29.84	29.72	29.30
Date	11	30	18	1	18	22	17	20	29	21	31	6	Nov. 18
Hour (Pacific Time)	8 P.M.	6 P.M.	5 P.M.	6 P.M.	1 P.M.	1 A.M.	6 P.M.	3 P.M.	3 A.M.	5 A.M.	6 P.M.	8 P.M.	1 P.M.

Air Temperatures (in Fahrenheit Degrees)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
Mean air temperature[3]	63.6	65.3	66.8	62.9	54.3	49.4	50.2	53.0	58.4	58.1	57.8	58.5	58.2
Mean air temperature at 8 A.M.	60.2	61.4	61.8	56.4	50.5	45.0	46.8	46.8	52.7	55.7	54.8	56.3	54.0
Mean air temperature at 8 P.M.	59.6	60.7	61.2	57.7	52.6	47.6	48.8	48.6	54.5	54.2	53.9	55.0	54.5
Mean maximum temperature[4]	73.6	75.1	78.3	74.7	60.7	56.1	56.6	61.6	68.4	67.7	65.9	67.6	67.2
Mean minimum temperature[5]	53.7	55.5	55.3	51.1	47.9	42.7	43.7	44.4	48.5	48.5	49.6	49.4	49.2
Highest daily mean[3]	78.1	74.0	86.8	77.0	63.4	58.0	57.8	59.6	74.6	69.2	64.0	71.0	86.8
Date	11	6	16	19	7	11	1	15	17	18	11	27	Sept. 16
Lowest daily mean[3]	58.5	61.2	58.7	55.5	49.2	42.0	48.8	46.6	49.0	53.5	52.5	50.7	42.0
Date	18	25	28	24	21	19	15	22	29	22	18	6	Dec. 19
Maximum temperature[4]	95.0	91.8	105.5	95.4	75.0	66.4	68.0	70.6	87.1	85.2	75.7	86.7	105.5
Date	11	6	16	1	7	1	4	28	17, 13	18	11	27	Sept. 16
Minimum temperature[5]	48.9	51.4	50.4	45.3	39.9	36.0	36.0	37.2	39.0	43.9	45.4	45.0	36.0
Date	14	14	29	27	24	15	9	6, 7	27	24, 28	6	9	Dec. 15, Jan. 9

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
Monthly range	46.1	40.4	55.1	50.1	35.1	30.4	32.0	33.4	48.1	41.3	30.3	41.7	40.4
Mean daily range	19.9	19.6	23.0	23.6	12.8	13.4	12.9	17.2	19.9	19.2	16.3	18.2	18.0
Maximum daily range	34.3	35.6	42.0	38.5	23.1	23.6	21.7	25.3	29.5	32.0	25.0	31.3	42.0
Date	5	6	15	1	7	9	4	7.	16	18	29	27	Sept. 15
Minimum daily range	10.8	11.0	12.8	10.4	3.2	3.7	3.0	6.3	6.6	8.9	6.5	4.8	3.0
Date	22	13	13	3	1	13	23	18	22	8	14	19	Jan. 23
Mean change from day to day	2.9	2.5	3.8	4.0	2.1	3.3	2.5	1.8	3.0	2.7	2.7	2.9	2.8

Moisture

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
Mean dew point at 8 A.M., °F	54	56	53	47	47	42	45	44	46	50	52	52	49
Mean dew point at 8 P.M., °F	54	56	53	48	49	46	47	46	49	50	52	52	50
Mean vapor pressure at 8 A.M., in.	.421	.447	.409	.328	.334	.276	.301	.289	.318	.362	.382	.398	.355
Mean vapor pressure at 8 P.M., in.	.414	.448	.403	.334	.348	.297	.317	.319	.346	.362	.382	.396	.359
Mean relative humidity, 8 A.M., %	81	82	76	75	93	92	95	89	82	82	92	88	86
Mean relative humidity, 8 P.M., %	82	86	77	72	88	91	96	85	82	87	93	91	86
Mean cloudiness at 8 A.M.	.5	.6	.5	.4	.7	.6	.6	.4	.5	.6	.6	.7	.6
Mean cloudiness at 8 P.M.	.4	.4	.3	.3	.5	.5	.5	.3	.4	.5	.6	.5	.4
Total precipitation, all kinds, in.[6]	0.19	0.03	·	0.36	5.88	6.98	12.74	3.98	0.99	1.33	0.62	0.48	33.58
Max. precipitation in 24 hrs., in.[6]	0.10	0.03	·	0.36	1.40	1.58	2.28	1.79	0.94	0.58	0.21	0.33	2.28
Date[7]	23	27	....	31	18	30	12	20	29	4	7	6	Jan. 12

[1] Reduced to a true 24-hour mean by corrections furnished by the United States Weather Bureau.

[2] From barograph corrected.

[3] $\frac{1}{2}$ (maximum + minimum).

[4] From mercurial maximum thermometer, United States Weather Bureau pattern.

[5] From alcohol minimum thermometer, United States Weather Bureau pattern.

[6] Includes rain, dew, and fog. In accordance with the recommendation of the International Meteorological Committee, absence of precipitation is indicated by a dot (·).

[7] Amounts to 8 P.M. Pacific Standard time of the date indicated.

TABLE IIa—ENGLISH UNITS—(*Continued*)

Weather (Number of Days)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
Clear	14	13	13	15	7	7	10	12	16	12	13	10	142
Partly cloudy	7	12	13	10	10	8	3	6	5	10	8	13	105
Cloudy	10	6	4	6	13	16	18	10	10	8	10	7	118
With fog[8]	3	2	2	6	7	1	1	2	1	1	1	2	29
With frost	0	0	0	0	3	6	7	6	1	0	0	0	23
With thunderstorms	0	0	0	0	0	0	2	1	0	0	1	0	4
With hail	0	0	0	0	0	0	1	0	1	0	1	0	3
With precipit'n $\geqq$ 0.2 mm., 0.01 in.	2	1	0	1	17	13	16	8	3	7	6	4	78
With precipit'n $\geqq$ 1.0 mm., 0.04 in.	2	0	0	1	12	12	15	6	1	7	5	3	64
Longest period with precipitation	2	1	0	1	6	5	7	7	2	3	4	2	7
Longest period without precipit'n	21	25	30	30	4	10	4	15	26	10	6	11	63[9]

Wind at 8^hrs and 20^hrs (Number of Observations)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
North	0	1	5	4	13	3	2	3	3	6	0	1	41
Northeast	0	0	0	3	2	4	0	0	3	0	0	0	12
East	0	0	0	3	0	4	0	2	1	0	0	0	10
Southeast	0	3	0	3	10	8	3	12	7	3	8	11	68
South	24	33	12	19	19	28	40	17	22	26	18	19	277
Southwest	18	3	10	9	5	3	5	3	4	7	20	14	101
West	5	10	12	5	3	0	0	2	2	2	4	6	51
Northwest	6	1	3	2	2	2	0	2	5	4	4	3	34
Calm	9	11	18	14	6	10	12	15	15	12	8	6	136

Prevailing Wind (Number of Days)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year
North	0	0	4	1	6	1	0	2	2	1	0	0	17
Northeast	0	0	0	2	0	5	0	1	4	0	0	0	12
East	0	0	0	1	0	0	1	2	2	0	0	0	6
Southeast	0	0	0	0	4	4	4	5	4	1	0	0	22
South	2	11	4	4	9	12	21	7	7	10	7	5	99
Southwest	14	11	6	11	8	5	2	9	8	7	15	14	110
West	9	8	6	6	0	1	1	2	1	2	7	9	52
Northwest	5	1	7	6	3	3	2	0	3	9	2	2	43
Calm	1	0	8	0	0	0	0	0	0	0	0	0	4

[8] Includes only days on which fog lay on the Campus. See Internationaler Meteorologischer Kodex, ed. 2, p. 18: "Fog is to be recorded only when the observer is enveloped in it."

[9] From August 29 to October 30 inclusive.

EXTRACTS FROM THE MONTHLY REPORTS

The first half of JULY, 1913, was a period of unusually high temperatures for this month; while the record of maximum temperature was not equaled, the temperatures reached (303.6° A, 87.2° F, on the 5th, 301.9° A, 84.0° F, on the 10th, and 308.0° A, 95.0° F, on the 11th) are among the highest recorded in July at Berkeley in twenty-seven years. These two weeks were also a period of clear skies, no day being cloudy and only two days partly cloudy. The second half of the month was cooler and more cloudy than the first half, so that the mean temperature and the number of cloudy days were not far from the average. The differences in exposure of the thermometers show less in the mean monthly temperatures than has usually been the case. The thermometers exposed in the window shelter give the following results: mean maximum temperature, 295.2° A, 72.0° F; mean minimum, 286.2° A, 55.8° F; mean monthly, 290.7° A, 63.9° F; maximum, 306.2° A, 91.8° F, on the 11th; and minimum, 284.0° A, 51.1° F, on the 14th and again on the 15th.

Cloudiness at both morning and evening observations was somewhat less than the average, which is, perhaps, due to the relatively high percentage of west and northwest wind; these two directions prevailed on as many days as the southwest wind, which is the usual direction in July. True fog was recorded on the evening of the 17th and on the evening of the 21st, lasting until the morning of the 22nd, when rain began. "High fog" (velo cloud) was observed on the 19th, 28th, and 29th in addition to the days on which true fog was observed. Because of the local topography of Berkeley it is hardly possible to make a general statement concerning fog conditions; the personal judgment of the observers is such an important factor that averages of number of days with fog must be regarded as approximations; it is probable that the amount of fog during July, 1913, was considerably less than the average for the month.

The most unusual feature of the weather of July, 1913, was the occurrence of 4.8 mm., 0.19 in., of precipitation on the 22nd and 23rd; this amount was practically all in the form of rain, although a trace of precipitation from fog was recorded before the rain began on the 22nd. July, 1913, is second in the amount of rain in the Julys of the past twenty-seven years. The amount of this month was exceeded only in July, 1891, when 11.2 mm., 0.44 in., fell on the 9th. The only other July precipitation worthy of note was 1.0 mm., 0.04 in., in 1895; all the rest was in amounts of about 0.2 mm., 0.01 in., and was probably collected from fog. The amount in 1913 was sufficient to change the average amount for July from 0.5 mm., 0.02 in., to 0.8 mm., 0.03 in.

During AUGUST, 1913, there was more sunshine than is usual in the month of August This is shown by the larger number of clear days and the low mean cloudiness, and also by the higher mean temperatures, a condition which occurred in the window shelter as well as in the standard shelter. The results from the window shelter are as follows: mean for the month, 291.3° A, 64.9° F; mean maximum, 295.5° A, 72.5° A; mean

results: Mean, 291.2° A, 64.8° F; mean maximum, 295.8° A, 73.0° F; mean minimum, 286.7° A, 56.6° F; maximum, 309.2° A, 97.2° F, on the 16th; and minimum, 283.3° A, 50.5° F, on the 28th. Evening minima occurred on the 17th and 22nd; on all other days the minimum occurred in the early morning.

While the actual amount of water vapor in the air was about the average, September, 1913, was noticeably drier than usual because of the high temperatures. The relative humidities were low and the amount of cloud and number of cloudy days smaller than usual because of this; but the mean dew points were about the average. Fog was recorded on the evening of the 19th and on the morning of the 22nd; "high fog" (velo cloud) on the evening of the 6th and the mornings of the 21st and 28th.

The month was the sixth rainless September since the establishment of the station. The seasonal precipitation to the end of the month was 11.2 mm., 0.44 in., less than the average, although there was an excess of 3.6 mm., 0.14 in., at the beginning of the month The barograph trace shows that the cyclones, characteristic of the rainy months, have not yet become a factor of the weather of the season; and this is the reason for the low cloudiness and lack of rain.

The wind was generally light; on the 23rd a north wind with a velocity of from 8 to 13 meters per second, 20 to 30 miles per hour, blew during the early morning and forenoon hours.

OCTOBER, 1913, was warm and dry. The mean evening temperatures and mean minima are lower than the normals, because of freer exposure conditions which permit more effective cooling and probably represent apparent rather than real departures from the average. That the month was warmer than the average is also shown by the fact that the highest temperature is a new record, and that the maximum under the conditions of exposure of the first twenty-five years has been exceeded in only three years—1887, 1899, and 1901. The highest previous temperature for October was 307.4° A, 94.0° F, on the 8th, 1899; the new record is due to the change in the exposure. Under the conditions of exposure which were standard prior to 1912, the temperatures for October, 1913, were as follows: mean for the month, 288.8° A, 60.4° F; mean maximum, 293.4° A, 68.7° F; mean minimum, 284.1° A, 52.0° F; maximum, 304.7° A, 89.1° F, on the 1st; and minimum, 281.3° A, 47.0° F, on the 27th.

The change from day to day was about 43 per cent greater than the normal; this seems to be the result of local wind and moisture conditions rather than to direct cyclonic control. The changes were large throughout the month, and the size of the mean is not due to conditions on particular days.

A trace of rain occurred on the morning of the 13th, and a rather important fall on the afternoon and evening of the 31st. The total fall on the 31st was about 11.4 mm., 0.45 in., but in order to keep the tabular record uniform the meteorological day of the station, which is the twenty-four hours ending at 20^{hrs}, 8 P.M., the amount to that time has been entered in the table. The rain which began on the 31st continued on November 1.

The wind velocity was as usual light, except that winds with velocities of

January, 1914, was a wet month; the amount of rain for the month was exceeded only in 1909 with 333.0 mm., 13.11 in., and 1911 with 406.2 mm., 15.99 in. The number of rainy days exceeded in 1890, 1909, and 1911, with 21, 25, and 17 respectively. The number of cloudy days was equaled in 1909, but has never been exceeded. The rain appears from the barograph trace to have been the result of five more or less distinct cyclones. Thunder and hail occurred on the morning of the 18th, and a thunderstorm with lightning and heavy rain on the evening of the 25th. Considerable damage was done by this storm to electrical installations, and a building in Albany was reported struck by lightning and burned. The storm was the most severe since the establishment of the Meteorological Station in 1886.

The temperature conditions were not far from the average for the month. The record from the window shelter was mean, 282.2° A, 48.6° F; mean maximum, 284.9° A, 53.4° F; mean minimum, 279.6° A, 43.9° F; maximum, 289.1° A, 61.0° F, on the 3rd; and minimum, 274.7° A, 35.1° F, on the 10th. Terrestrial radiation temperatures were obtained on five nights; the lowest minima on the campus averaged 5.9° A, 10.7° F, below the air minima.

In general the wind was light, although probably the velocity was above normal. On the 25th the velocity was perhaps as high as 13 meters per second (30 miles an hour); and at times during the rainy nights there was considerable wind.

The first fifteen days of February, 1914, were rainless, although there was a considerable amount of cloud and southerly wind during this period. The rain occurred as the result of a single cyclone or of two closely related cyclones from the 16th to the 22nd (see pl. 54). Although the number of days with rain was but one less than the average, the distribution of rain through the month was peculiar; with the exception of 0.2 mm., 0.01 in., during the night of the 24th to 25th, all the rain fell on seven consecutive days. The third thunderstorm of the season occurred on the 19th; three thunderstorms in a single season is large for this region.

Temperature and moisture conditons for the month were not unusual, except that the daily ranges of temperature were large, and there was no day with a range of less than 3° A, 6° F. The pressure was unusually high except during the week of rain, although the average for the month was not far from the normal.

The temperature record from the window shelter was as follows: mean for the month, 283.6° A, 51.0° F; mean maximum, 287.0° A, 57.2° F; mean minimum, 280.1° A, 44.7° F; maximum, 290.8° A, 64.0° F, on the 15th; and minimum, 275.9° A, 37.2° F, on the 6th. Terrestrial radiation temperatures were obtained on eight nights early in the month; the average of the lowest radiation temperatures on the campus was 6.4° A, 11.6° F, below the minimum air temperatures on the same nights. The minimum temperature for the day was recorded in the evening on the 19th and 20th, but in both cases the morning minimum was less than a degree higher. Both occurred during the week of cloud and rain.

The wind velocity was low, as usual, although the rains were accompanied by brisk winds, especially at night.

served on eleven days, and there was a considerable amount of southwest wind.

The summary of the temperatures under the former exposure conditions is as follows: mean for the month, 288.3° A, 59.6° F; mean maximum, 291.9° A, 66.1° F; mean minimum, 283.7° A, 51.2° F; maximum, 295.8° A, 73.0° F, on the 29th; and minimum, 281.6° A, 47.4° F, on the 6th.

Rain in significant amounts occurred in three periods—the 7th, the 14th and 15th, and from the 22nd to 25th. The barograph trace shows no clear depression for the first; during the last two moderate depressions are shown. Thunder and hail occurred about 1:30 A.M. on the 22nd. The seasonal precipitation to the end of the month was more than the average, although the rainfall for the month was but 56 per cent of the average for May.

June, 1914, was a cold month, which was mainly the result of the large amount of velo cloud ("high fog"), this type of cloud being recorded on more than one-third of the days. The maximum and minimum temperatures were lower under the old as well as under the new conditions of exposure. The summary of temperatures from the window shelter is as follows: mean for the month, 287.7° A, 58.4° F; mean maximum, 292.4° A, 67.0° F; mean minimum, 282.9° A, 49.8° F; maximum, 301.3° A, 83.0° F, on the 27th; and minimum, 281.2° A, 46.7° F, on the 9th.

The large amount of cloud is due to the velo cloud and also to a considerable amount of higher cloud of cyclonic origin. The barograph trace shows the usual summer characteristics, the double diurnal swing; there were no other variations of consequence, except a depression of 10.2 millibars, 0.30 in., beginning at noon on the 5th and ending at noon on the 8th. It was during this depression that 9.6 mm., 0.38 in, of the rain occurred. Rain also fell on the 19th and on the 24th, but on both these dates the barograph trace shows no depression, although the rain was evidently of cyclonic origin. The precipitation for the month was more than twice the average for June. Years in which a greater amount was recorded in June than in June, 1914, are 1888, 1894, 1906, 1907, and 1912. No rain was recorded in eight Junes and a trace in four other Junes. The amount for June, 1914, was therefore unusually large.

ATMOSPHERIC PRESSURE

Atmospheric pressure was measured during the year by a Fortin cistern mercurial barometer of the United States Weather Bureau pattern, made by H. J. Green; observations of pressure were made twice daily, at 8^{hrs} and 20^{hrs}, mean civil time of the 120th meridian west from Greenwich (8 A.M. and 8 P.M., Pacific Standard time), which corresponds to 16^{hrs} and 4^{hrs}, Greenwich mean civil time. The barometer in use reads by a vernier to

0.002 inch (0.05 mm.). Readings have been made in inches and corrected for temperature and local gravity by the use of the tables published by the United States Weather Bureau.[5] Reduction tables for the altitude (98 meters, 322 feet) have been prepared from the Smithsonian Meteorological Tables. The sea-level equivalents have been converted to rational units by the use of the tables published in the *Observer's Handbook,* 1913.[6] Although this procedure is awkward, the station does not possess a barometer graduated for the use of the rational absolute units directly. The gravity correction for the University campus at the elevation of the barometer is —0.020 inch (—0.51 mm.). For practically all temperatures which occur at Berkeley the reduction to sea-level is +0.35 inch (+11.9 millibars), so that the station pressures may readily be determined from Table II. Mean pressures, corrected to 24 hours, have been obtained from the means of the observed readings for each month. Corrections to reduce the means determined arithmetically from the observations at 8^{hrs} and 20^{hrs} (8 A.M. and 8 P.M.) have been furnished for San Francisco by the United States Weather Bureau. The same corrections are used for Berkeley, as the distance is so small that any difference would be inappreciable and there are, as yet, no data from which the diurnal pressure variations and the mean hourly pressures can be determined; the barograph records for Berkeley cover a period of less than three years, although their number is being constantly increased. Table III shows the corrections which have been applied to the means deduced from the twice daily observations to obtain the true monthly mean pressures; the mean pressure for the year, 1017.2 millibars (763.0 millimeters or 30.04 inches) is the arithmetical mean of the corrected monthly means.

The highest monthly mean was that of February, 1019.5 millibars (764.8 millimeters or 30.11 inches of mercury under standard conditions), and the lowest monthly mean was that of June, 1015.0 millibars (761.5 millimeters or 29.98 inches). The re-

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[5] Marvin, C. F., Barometers and the Measurement of Atmospheric Pressure, Circular F, Instrument Division, U. S. Weather Bureau, 4th ed., 1912.

[6] (British) Meteorological Office, The Observer's Handbook, 1913, M. O. 191, London, 1913, Appendix D, Table iv (a).

TABLE III

Corrections to reduce barometric means deduced from observations at 8^{hrs} and 20^{hrs} mean civil time of the 120th meridian (8 A.M. and 8 P.M., Pacific Standard time) to a true daily mean.

BERKELEY, CALIFORNIA

Month	8^{hrs} Mb.	20^{hrs} Mb.	$8 + 20^{hrs}$ Mb.	8 a.m. In.	8 p.m. In.	8 a.m. + 8 p.m. In.
July	—0.85	+0.51	—0.17	—0.025	+0.015	—0.005
August	—0.95	+0.44	—0.26	—0.028	+0.013	—0.008
September	—1.02	+0.44	—0.29	—0.030	+0.013	—0.008
October	—0.82	+0.34	—0.24	—0.024	+0.010	—0.007
November	—0.75	+0.17	—0.29	—0.022	+0.005	—0.008
December	—0.61	+0.14	—0.24	—0.018	+0.004	—0.007
January	—0.48	+0.31	—0.08	—0.014	+0.009	—0.002
February	—0.61	+0.41	—0.10	—0.018	+0.012	—0.003
March	—0.51	+0.44	—0.04	—0.015	+0.013	—0.001
April	—0.71	+0.51	—0.10	—0.021	+0.015	—0.003
May	—0.68	+0.44	—0.12	—0.020	+0.013	—0.004
June	—0.71	+0.51	—0.10	—0.021	+0.015	—0.003
Year	—0.72	+0.39	—0.17	—0.021	+0.011	—0.005

NOTE.—Corrections the same as those for San Francisco, furnished by the United States Weather Bureau.

lations between the pressures and the temperatures at Berkeley have not yet been studied sufficiently to show with any degree of certainty which is the controlling factor. That the general pressure conditions of the continent exert a control over the storm tracks and hence over the precipitation is not questioned, but the relations between the general pressure conditions and the temperatures at particular places is much less clear. Cloudy weather, which is usually the result of the passage of cyclones, prevents low minima and high maxima of temperature, and anticyclonic weather is conducive to large temperature ranges; but how far mean conditions are controlled by pressure distribution has not yet been determined.

The pressure data presented in Table II include, besides the mean pressures, the highest and lowest pressures recorded during

TABLE IV

Monthly, Seasonal, and Annual Mean Temperatures and Averages for Berkeley, California, 1887–1913, in Absolute Degrees

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal	Year	Annual
1887–88	290.5	288.1	290.7	290.7	285.4	282.8	279.9	283.9	283.4	285.9	286.8	290.2	286.6	....	....
1888–89	289.1	289.9	290.7	289.3	286.2	283.7	281.8	283.7	286.1	286.9	287.6	289.2	287.0	1888	286.8
1889–90	289.1	289.5	289.7	288.6	286.6	282.2	279.6	282.0	284.4	285.6	288.1	289.6	286.2	1889	286.7
1890–91	289.3	291.2	291.2	289.7	287.6	282.9	283.9	282.9	284.9	285.1	287.1	290.3	287.2	1890	286.8
1891–92	291.0	291.4	290.4	288.4	288.0	282.7	283.3	284.8	284.7	284.8	287.8	288.3	287.1	1891	287.2
1892–93	289.1	290.9	289.3	288.2	286.0	282.9	281.2	282.1	283.3	284.2	287.4	289.1	286.1	1892	286.7
1893–94	290.1	288.9	288.7	287.1	285.4	283.3	280.8	281.1	282.9	286.1	286.9	288.2	285.8	1893	285.9
1894–95	289.1	290.3	291.0	288.1	287.1	281.9	281.1	284.3	283.8	285.8	288.6	289.8	286.7	1894	286.1
1895–96	290.1	289.8	289.4	288.1	285.7	281.2	283.4	284.9	285.0	287.2	287.3	289.7	286.8	1895	286.5
1896–97	291.0	290.8	289.2	288.3	283.7	283.4	280.8	282.3	281.7	287.3	288.6	290.2	286.4	1896	287.0
1897–98	290.4	289.3	290.0	286.4	283.6	282.0	280.1	282.8	283.4	286.5	285.9	290.3	285.9	1897	286.0
1898–99	289.4	289.5	289.2	288.9	285.1	282.0	283.0	283.4	284.1	286.0	286.0	289.2	286.3	1898	286.1
1899–1900	288.7	289.2	289.1	287.7	285.9	282.1	284.0	283.9	285.7	285.3	288.8	289.7	286.7	1899	286.2
1900–01	290.3	290.0	290.7	288.1	286.2	282.8	282.3	283.7	286.0	284.8	286.8	289.3	286.7	1900	287.1
1901–02	289.0	289.0	288.7	289.9	286.8	283.3	280.6	284.2	283.2	285.6	286.9	289.4	286.4	1901	286.6

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal	Year	Annual
1902–03	290.2	290.4	290.6	288.0	284.2	282.0	281.0	280.8	283.4	284.9	287.2	290.2	286.1	1902	286.3
1903–04	289.1	288.9	289.2	288.6	285.1	282.4	281.3	281.6	283.0	286.1	288.6	289.5	286.1	1903	285.9
1904–05	288.3	288.0	290.4	287.8	285.1	281.0	282.3	283.3	285.4	285.8	286.1	287 7	285.9	1904	285.9
1905–06	289.3	288.4	288.8	287.4	284.6	281.6	282.0	285.7	285.0	286.6	287.2	289.9	286.4	1905	285.9
1906–07	290.4	289.4	290.1	289.3	285.3	282.3	281.1	285.6	283.2	287.1	287.7	288.9	286.7	1906	286.9
1907–08	289.8	289.9	289.2	288.8	285.8	283.3	....	....	284.6	286.9	287.2	288.4	BR	1907	286.7
1908–09	289.9	289.1	289.6	287.7	284.7	280.6	283.2	282.8	283.3	286.9	287.0	288.8	286.1	1908	BR
1909–10	290.1	289.3	290.2	287.8	284.5	281.7	279.8	281.8	285.1	286.9	289.0	288 4	286.2	1909	286.3
1910–11	288.9	287.9	287.6	288.3	284.3	283.2	282.3	280.9	284.9	285.3	287.0	287.8	285.7	1910	285.9
1911–12	288.3	288.0	288.0	288 1	285.2	282.0	282.9	284.0	283.4	284.7	288.0	289.9	286.0	1911	285.6
1912–13	289.4	290.2	281.5	288.6	286.1	283.1	280.9	283.2	284.2	285.8	287.4	289.3	286.4	1912	286.4
1913–14	290.6	291.5	292.3	290.2	285.4	282.6	283.1	284.6	287.7	287.5	287.3	287 8	287.6	1913	287.0
Averages	289.6	289.6	289.8	288.4	285.5	282.4	281.7	283.2	284.3	286.0	287.4	289.2	286.4	....	286.4

NOTE.—A change in the conditions of thermometer exposure April 1, 1912, makes the means before not strictly comparable with those after that date. Minimum temperatures for January and February, 1908, are not available.

TABLE IVa

Monthly, Seasonal, and Annual Mean Temperatures and Averages for Berkeley, California, 1887–1913, in Fahrenheit Degrees

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal	Year	Annual
1887–88	63.5	59.2	63.9	63.8	54.4	49.6	44.4	51.6	50.8	55.2	56.8	63.0	56.4	....	......
1888–89	61.2	62.4	63.9	61.2	55.8	51.2	47.8	51.2	55.5	57.1	58.2	61.1	57.2	1888	56.5
1889–90	61.0	61.7	62.0	60.1	56.4	48.5	43.8	48.2	52.6	54.6	59.2	61.8	55.8	1889	56.7
1890–91	61.4	64.8	64.8	62.0	58.2	49.8	51.7	49.8	53.4	53.8	57.4	63.2	57.5	1890	56.8
1891–92	64.4	65.2	63.4	59.8	59.0	49.4	50.6	53.3	53.0	53.2	58.6	59.6	57.5	1891	57.5
1892–93	61.0	64.2	61.4	59.3	55.4	49.8	46.8	48.4	50.6	52.1	58.0	61.0	55.7	1892	56.5
1893–94	61.8	60.6	60.2	57.4	54.3	50.6	46.0	46.6	49.8	55.6	57.0	59.4	54.9	1893	55.2
1894–95	60.9	63.0	64.4	59.1	57.4	48.0	46.6	52.3	51.5	55.0	60.0	62.3	56.7	1894	55.6
1895–96	62.8	62.2	61.5	59.2	54.8	46.8	50.8	53.4	53.6	57.6	57.7	62.0	56.9	1895	56.2
1896–97	64.4	64.1	61.2	59.5	51.2	50.8	46.1	48.7	47.7	57.7	60.0	63.0	56.2	1896	57.0
1897–98	63.3	61.1	62.6	56.2	51.0	48.2	44.8	49.7	50.8	56.3	55.2	63.1	55.2	1897	55.5
1898–99	61.6	61.7	61.2	60.6	53.7	48.2	50.0	50.8	52.0	55.4	55.4	61.2	56.0	1898	55.6
1899–1900	60.2	61.2	60.9	58.4	55 2	48.3	51.8	51.6	54.8	54.2	60.4	62.1	56.6	1899	55.8
1900–01	63.2	62.6	63.8	59.1	55.8	49.7	48.8	51.2	55.4	53.2	56.8	61.1	56.7	1900	57.4
1901–02	60.8	60.8	60.2	62.4	56.8	50.5	45.6	52.1	50.4	54.7	57.0	61.6	56.1	1901	56.5

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal	Year	Annual
1902–03	63.0	63.3	63.6	59.0	52.1	48.2	46.4	46.1	50.8	53.4	57.6	62.9	55.5	1902	55.9
1903–04	61.0	60.7	61.2	60.0	53 8	49.0	46.9	47.4	50.0	55.4	60.0	61.7	55.6	1903	55.2
1904–05	59.6	59.0	63.4	58.6	53.8	46.4	48.7	50.6	54.3	55.1	55.6	58.4	55.3	1904	55.2
1905–06	61.4	59.8	60.4	58.0	52.9	47.4	48.2	54.8	53.6	56.8	57.6	62.4	56.1	1905	55.2
1906–07	63.4	61.6	62.8	61.3	54.2	48.7	46 6	54.7	50.4	57.4	58.5	60.6	56.7	1906	57.1
1907–08	62.2	62.4	61.2	60.4	55 0	50.6	......	......	52.8	57.0	57.5	59.7	BR	1907	56.7
1908–09	62.5	61.0	61.8	58.4	53.0	45.6	50.4	49.6	50.5	57.0	57.2	60.4	55.6	1908	BR
1909–10	62.8	61.4	62.9	58.6	52.7	47.6	44.2	47.9	53.8	57.0	60.8	59.8	55.8	1909	55.9
1910–11	60.6	58.9	58.3	59.6	52.4	50.4	48.8	46.2	53.4	54.2	57.2	58.6	54.9	1910	55.3
1911–12	59.6	59.0	59.0	59.1	54.0	48.2	49.8	51.8	50.8	53.0	59.0	62.5	55.5	1911	54.8
1912–13	61.5	63.0	65.3	60.0	55 6	50.2	46.2	51.4	51 8	56.0	58.4	61.0	56.7	1912	56.9
1913–14	63.6	65.3	66.8	62.9	54.3	49.4	50.2	53.0	58.4	58.1	57.8	58.5	58.2	1913	57.0
Averages	61.9	61.8	62.1	59.7	54.5	49.0	47.7	50.4	52.3	55.4	58.0	61.1	56.1	....	56.1

NOTE.—A change in the conditions of thermometer exposure April 1, 1912, makes the means before not strictly comparable with those after that date. Minimum temperatures for January and February, 1908, are not available.

data suggested by the International Meteorological Committee and is the same as the data published a year ago. These are the mean temperatures for each month and for the warmest and coldest day of each month, determined from the maximum and minimum temperatures in conformity with the practice of the Weather Bureau, as this is recognized as the best practice where the observation hours are only twice daily; and also, as mean temperatures for Berkeley should be comparable with those of the other stations of the United States, the method by which these means are deduced should be the same. The data for the year have been determined from the monthly data. In addition to these means, the mean of the maxima and the mean of the minima have been determined for each month and for the year, and also the highest and lowest temperature for each month. Temperatures for the observation hours and ranges and diurnal variability have also been computed.

The temperatures stated are all the results of observation of glass thermometers of the United States Weather Bureau pattern, exposed in the co-operative observer's shelter, as stated earlier in this report. All temperatures stated in tables IV and V for dates since April 1, 1912, were observed under the same conditions; temperatures prior to that date were observed from

TABLE V

EXTREME TEMPERATURES JULY 1, 1887, TO JUNE 30, 1914

	Maximum			Minimum		
Month	° A	° F	Date	° A	° F	Date
July	309.3	97.3	7, 1905	278.7	42.3	29, 1899
August	307.1	93.4	22, 1891	281.0	46.4	31, 1905
September	**313.8**	**105.5**	16, 1914	280.7	45.9	28, 1905
October	308.2	95.4	1, 1914	277.1	39.3	18, 1905
November	300.8	82.0	16, 1895	273.6	33.0	28, 1905
December	293.9	69.6	24, 1901	272.4	31.0	24, 1905
January	298.0	77.0	26, 1899	**269.1**	**24.9**	14, 1888
February	299.4	79.5	18, 1899	271.4	29.2	12, 1905
March	303.6	87.1	17, 18, 1914	274.1	33.9	30, 1905
April	303.3	86.6	24, 1913	275.2	36.0	19, 1896
May	306.6	92.5	26, 1896	277.4	39.9	1, 1899
June	311.4	101.1	6, 1903	278.8	42.4	2, 1903
Year	313.8	105.5	Sept. 16, 1914	269.1	24.9	Jan. 14, 1888

glass thermometers exposed in the window shelter of the observatory. The results are therefore not strictly comparable, and as yet it has not been possible to determine the differences or to reduce the two sets of observations to a homogeneous series.

Tables IV and V have been compiled to show the complete climatic temperature data for the station in summarized form. These tables are self-explanatory. The means in Table IV are the arithmetic averages of all data as computed. Temperatures observed through the year in the window shelter indicate that

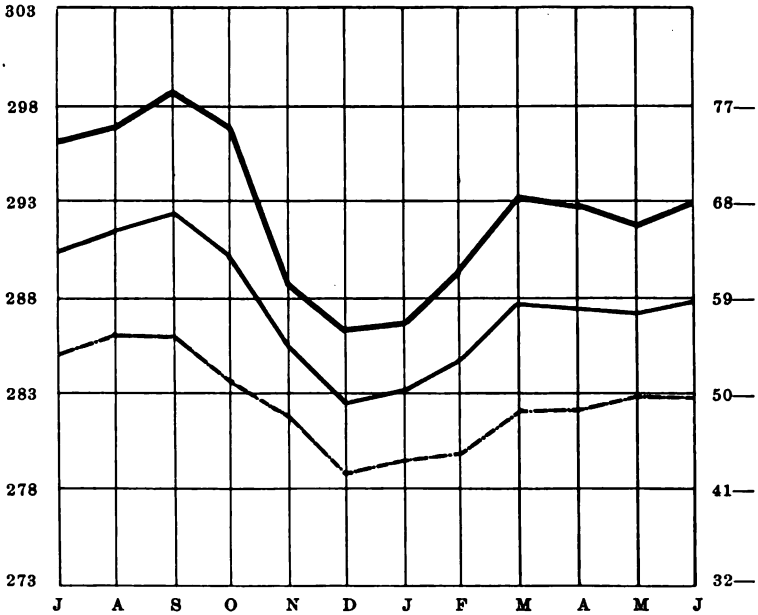

Fig. 3

the means deduced from this exposure are about half a degree Absolute (one degree Fahrenheit) lower than those deduced from the standard shelter.

The annual march of temperature for the year ending June 30, 1914, is shown by tables II and IV, and is graphically represented by curve Mo in figure 3. The characteristic features of the march for this year are an increase to a maximum in September, a decrease to a minimum in December, an increase to a second and lesser maximum in March, a slight secondary minimum in May, and an increase to the end of the year. This is

not strictly the normal curve, which has its maximum in September and its minimum in January, but the curve for 1913–1914 has (with the exceptions noted) the main characteristics of the normal. The data and the curve show the warmest month (September) to be that in which the highest temperature for the year was observed, but the minimum monthly mean in December occurred a month before the lowest temperature, which was observed on January 9.

The parallelism, noted in 1912–1913, between the march of mean monthly, mean monthly maximum, and mean monthly minimum temperatures is also to be seen in figure 3. The causes of this parallelism were discussed on pages 276–277 of the report for 1912–1913. In 1913–1914 this condition is not as well marked, the most noticeable departure being in the spring, when the mean range for May was so much less than that for April that it appears distinctly in the figure.

The extreme temperatures for the year were maximum 313.8° A, 105.5° F, on September 16, which was also the warmest day of the year. As has usually been the case, the highest temperature occurred during a period of "north wind" weather with foehn conditions when the air was in part mechanically warmed by compression. The minimum temperature, 275.2° A, 36.0° F, was observed on December 15 and January 9, neither date being the coldest day of the year. In both cases the low temperature occurred during a period of anticyclonic weather with strong local radiation. The anticyclone on December 15 does not seem to have been as effective as a control of surface temperatures as that of January 9, as the terrestrial radiation temperatures were nearly a degree Absolute (between a degree and a half and two degrees Fahrenheit) lower on the later date.

For the study of frost conditions terrestrial radiation thermometers were employed from time to time throughout the year, but no systematic campaign was practicable under the conditions and the results are very fragmentary. Such results as were obtained are stated in the monthly summaries on pages 394 to 400. The statements of the observation of frost by days are given in Table II. As was stated last year, this number is the observed frost on the campus and does not show the general conditions.

23.6° F; this is the same month as last year and the range was about the same. The month with the smallest mean daily range was January, with 7.1° A, 12.9° F. This is the same month as 1912–1913, but the range then was greater, 8.9° A, 16.0° F. The greatest and smallest ranges in a single day have also been recorded for each month and for the year. The greatest range in a day was 23.3° A, 42.0° F, on September 15, the day before the warmest day of the year, at a time when cyclonic control was not effective. The smallest range in a day was 1.7° A, 3.0° F, on January 23, at the beginning of a cyclone of considerable importance (see Table XI, on p. 430). These ranges are all non-periodic, that is, they represent the difference between the maximum and minimum temperatures, no matter at what time these extremes occurred. The periodic ranges, or differences between the warmest and coldest hours, have not been determined. The hourly temperatures for Berkeley have not been determined, as the thermograph record covers a period of only two years, which is not regarded as sufficient to establish the relations. For this station it is probable that the periodic ranges are only slightly smaller than the non-periodic. The highest temperatures practically always occur in the mid-afternoon hours, although not always at the same time, and the lowest temperatures in the early morning, although evening minima are by no means unknown (see "Extracts from the Monthly Reports," on pp. 394 to 400).

The monthly ranges were generally more than twice the mean daily ranges. The mean monthly range for the year was 22.4° A, 40.4° F. The greatest monthly range was 30.6° A, 55.1° F, in September, and the least was 16.9° A, 30.3° F, in May. The monthly range for December was practically the same as that for May. In 1912–1913 December was the month with the smallest diurnal range. As was stated in the last report, the relations existing between the monthly range and the daily ranges are not very clear, beyond the fact that the monthly range must be greater than the maximum daily range. The difference between the warmest and coldest day of each month was in nine of the twelve months somewhat less than the mean daily range; in September, March, and June it was more than the mean daily range. In no case did the difference amount to more than three

Absolute (six Fahrenheit) degrees; this difference was, however, in some cases nearly 50 per cent of the difference between the warmest and coldest day. All these statements of temperature difference serve merely to show the rather uniform temperature conditions of Berkeley.

The relation between daily and annual ranges of temperature is one which shows the "meteorological latitude" of a station as clearly as any single statement. The annual mean range for 1913–1914, that is, the difference between the warmest and coldest months of the year, was 9.7° A, 16.6° F, which is only slightly less than the mean daily range. The correspondence between these ranges is not as close as it was for the year 1912–1913, but it still shows that Berkeley must be considered as located at the "meteorological tropic," where the conditons of the intertropical region, diurnal range in excess of the annual, and of the extratropical region, annual range in excess of the diurnal, are neither effective, and the condition is that of transition between the two regions. The difference between the highest and lowest temperatures for the year, the annual extreme range, was 38.6° A, 69.5° F, which is 2.0° A, 3.6° F, smaller than the extreme range for 1912–1913; this is due to the higher minimum, as the maximum recorded on September 16 was a record for the station. The difference between the mean temperature of the warmest and of the coldest day of the year was 24.8° A, 44.8° F.

ATMOSPHERIC MOISTURE

As no change has been made in the exposure conditions of the psychrometer since the previous report, the general statements in regard to atmospheric moisture made there[7] apply to the moisture data for 1913–1914. The range of the dew points was 7° A, 14° F, which is slightly less than that of the air temperatures at the observation hours. The highest mean dew point was 286° A, 56° F, at both 8^{hrs} and 20^{hrs} in August. The close relation between dew point and air temperature a year ago does not seem to hold in the present year, probably because of fog conditions. The lowest mean dew point was 279° A, 42° F, for

[7] Univ. Calif. Publ. Geog., vol. 1, no. 6, pp. 280–281, 1914.

December at 8^{hrs}. This was also the time of lowest mean temperature for the observation hours.

Vapor pressures, of course, follow the dew points. The range was 5.8 millibars (4.34 millimeters or 0.171 inch of mercury). The highest mean vapor pressure was 15.2 millibars (11.38 millimeters or 0.448 inch of mercury) for August at 20^{hrs} and the lowest 9.4 millibars (7.01 millimeters or 0.276 inch) for December at 8^{hrs}. The portion of the total pressure due to water vapor was therefore generally less than 2 per cent of the total atmospheric pressure at Berkeley.

Moisture has also been stated in terms of relative humidity. The mean relative humidity was 86 per cent at the observation hours. The highest mean for any month was 95 per cent for January at 8^{hrs}, and the lowest mean was 72 per cent for October at 20^{hrs}. Maximum humidities of 100 per cent were not uncommon during some of the fogs. The minimum humidity observed during the year was 8 per cent, registered by the Richard hair hygrograph at about $13\frac{1}{2}^{hrs}$ on September 16, the same date and time as the highest temperature of the year. This observation is subject to the errors of the instrument, but at the times when the indications of the hygrograph have been checked by the readings of the wet-and-dry-bulb thermometer these errors have been insignificant. It is therefore believed that this reading is not far from the actual humidity conditions at the time, particularly as the "north wind" (foehn) was blowing at the time.

The cloudiness record is still unsatisfactory and for that reason it has not been deemed advisable to carry the record to per cents, but rather to leave the averages in tenths. Mean cloudiness at the observation hours, which are the only times for which records are available, varied from three-tenths at the evening observation in September, October, and February, which it is interesting to note were non-stormy months during the part of the year when the coast fogs are infrequent, to seven-tenths in November, a stormy month, and in June, a month of considerable velo cloud ("high fog") and also cyclonic cloud. The cloudiness may be divided into the summer type, which is the low stratus cloud, called velo by Carpenter[8] and locally in California known

[8] Carpenter, Ford A., The Climate and Weather of San Diego, California, San Diego, 1913, pp. 5–7.

clear, partly cloudy, or cloudy; these three classes include all the days of the year regardless of other phenomena, such as rain. The relative number of clear, partly cloudy, and cloudy days is shown by figure 4. Fog, except when the vertical thickness was very small, has been regarded as cloud. On 142 days the sky was less than three-tenths cloudy through the day, or cloudy less than three-tenths of the time; these days were recorded as clear. In general, such days have been characterized by bright sun by day and clear starlight by night. In most cases there has been an entire absence of cloud or only a few cirrus wisps in the sky. The month with the largest number of clear days was March with 16, and those with the smallest number November and December, with seven clear days each.

As was stated in the previous report, the partly cloudy days are of two classes, those on which the sky was partly covered with cloud, generally of cyclonic origin, during the whole day, and those on which the sky was overcast, generally with the velo cloud, during the morning and evening hours. The first class includes the typical partly cloudy day of winter, the second is a summer type, except on a small number of occasions when the "tule" fog drifted south from the marshes at the mouth of the Sacramento River. There were 105 days recorded as partly cloudy during the year. The distinctions between partly cloudy and cloudy days in some cases has been arbitrary, but that between clear and partly cloudy has generally been sharp.

Days were recorded as cloudy when the sky was more than three-tenths cloudy through the day, or overcast more than three-tenths of the time. In summer such days were characterized by the velo cloud through the day and in winter by cyclonic cloud or rain. The number of cloudy days during the year was 118; the greatest number in a single month was 18 in January, and the smallest number was 4 in September.

FOG

The conditions under which fog occurs in Berkeley were fully described in the previous report, to which the reader is referred.[9]

[9] Univ. Calif. Publ. Geog., vol. 1, no. 6, pp. 283–284, 1914; see also McAdie, Alexander, The Clouds and Fogs of San Francisco (San Francisco, 1912)

Although the fog record is unsatisfactory, the conditions on the campus came within the definition of the International Meteorological Committee[10] on 29 dates during the year. The civil day is perhaps not a satisfactory time-unit for fog which begins in the evening and continues until the next morning, but the record has been kept by civil dates for want of automatic records which would give the number of hours with fog. The largest fog occurrence was November, when true fog occurred on 7 dates; the smallest in a single month was one day in each of five months. "High fog" was recorded on 27 other dates during the year. This type of cloud (velo) generally occurred on summer days with fog and not on winter days. In general, the velo cloud at Berkeley was confined to July, August, September, May, and June.

PRECIPITATION

The total precipitation of all kinds during the year 1913–1914 was 853.1 millimeters, 33.58 inches. The distribution of this precipitation by months is shown in Table II and also by figure 5. The comparative precipitation data for the whole period of the observations at Berkeley are given in Table VI,[11] on page 418. This table also includes the monthly means for the period of the record. The monthly amounts and the accumulated amount of rainfall to the end of each month for 1913–1914 and the averages for the twenty-seven years of the Berkeley record and also the accumulated departures for the year 1913–1914 have also been compiled and appear as Table IX, on page 424. Figure 5 (p. 422), which is similar to figure 4 in the report for 1913–1914, shows the average monthly rainfall at Berkeley (shaded) and the monthly amounts for 1913–1914. The scale of this figure has been changed from that used a year ago because some of the monthly amounts for 1913–1914 are of such magnitude that they could not be shown on the scale formerly used without materially increasing the size of the diagram.

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[10] See Internationaler Meteorologischer Kodex (ed. 2, Berlin, 1911), p. 18.

[11] For a discussion of the precipitation data for Berkeley see Reed, The Rainfall of Berkeley, California, Univ. Calif. Publ. Geog., vol. 1, no. 2, pp. 65–66, 1913.

TABLE VI

Monthly and Seasonal Precipitation, 1887–1914, in Millimeters

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal
1887–88	0.2	.	10.2	.	19.0	74.7	148.3	48.8	114.3	5.1	10.7	12.7	444.0
1888–89	.	.	15.0	0.5	68.8	96.3	19.8	13.7	192.5	18.3	38.1	1.5	464.5
1889–90	.	.	.	147.3	60.7	319.8	283.5	144.8	120.1	55.4	36.6	.0.0	1168.2
1890–91	.	.0.0	6.4	.	.	84.3	28.7	271.3	80.5	86.9	40.9	9.6	608.6
1891–92	11.2	.	18.8	4.6	25.6	158.0	59.4	106.7	91.4	42.7	75.4	.	593.8
1892–93	.0.0	.0.0	1.8	50.6	135.9	168.7	99.1	83.3	157.2	40.9	6.6	.	744.3
1893–94	.	0.5	9.6	13.2	132.6	66.6	242.3	95.8	23.1	14.5	51.0	28.2	676.9
1894–95	.	.	40.9	83.6	34.3	320.8	276.4	82.6	67.1	58.4	26 9	.	991.0
1895–96	1.0	.	32.5	1.8	45.2	55.9	289.6	9.1	74.4	170.7	23.9	.	704.1
1896–97	.0.0	22.9	19.3	48.5	130.8	125.0	94.2	118.9	151.6	11.1	5.1	7.6	735.0
1897–98	.	.	5.1	63.0	40.1	68.8	39.1	83.3	7.9	4.8	47.5	6.1	365.7
1898–99	.	1.0	23.6	47.8	24.6	31.0	149.9	5.3	335.0	39.6	43.2	1.3	702.3
1899–1900	.	.0.0	.	133.6	148.5	87.6	106.2	25.9	76.2	40.1	23.1	2.0	643.2
1900–01	.	0.5	1.2	35.8	128.0	46.5	148.6	150.1	23.1	77.7	25.9	.	637.4
1901–02	.0.0	0.8	33.0	17.2	80.3	37.6	34.5	265.9	105.9	39.4	42.9	.	656.7

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal
1902–03	.	.0.0	.	59.7	81.5	93.7	131.3	51.8	198.4	28.2	0.5	.0.0	645.1
1903–04	.	.	.	12.7	149.6	55.6	35.6	265.4	274.3	53.3	0.5	.0.0	853.1
1904–05	.	1.8	112.8	86.1	56.6	51.6	141.7	65.0	108.0	34.8	87.1	.	745.5
1905–04	.	.	.	.0.0	37.1	56.4	175.8	100.6	230.0	18.8	65.0	16.3	700.0
1906–07	.	1.0	4.3	.0.0	41.7	183.9	127.5	136.1	273.3	9.1	1.0	31.5	809.4
1907–08	.	.0.0	1.5	39.1	2.0	122.9	138.2	110.5	34.8	7.6	29.7	0.2	486.5
1908–09	.	.	2.3	24.9	46.5	66.6	333.0	235.2	92.5	0.5	.	.	801.5
1909–10	.	.	19.8	34.0	87.1	183.9	85.8	47.0	97.0	10.4	0.2	0.5	565.7
1910–11	.	.	1.5	15.2	22.1	45.7	406.2	102.9	131.3	39.6	6.9	1.0	772.4
1911–12	.0.0	.	.0.0	18.5	11.7	63.8	92.7	13.7	75.2	37.3	39.6	21.6	374.1
1912–13	.	.	37.1	17.8	98.8	41.2	96.0	16.3	50.3	14.5	25.2	.0.0	397.2
1913–14	4.8	0.8	.	9.1	149.4	177.3	323.6	101.1	25.2	33.8	15.8	12.2	853.1
Averages	0.6	1.0	14.7	35.7	68.8	106.8	152.1	101.9	119.1	36.8	28.5	5.6	671.6

NOTE.—In accordance with the recommendation of the International Meteorological Committee, absence of precipitation is indicated by a dot (.); a trace, amount too small to measure, by the symbol .0.0.

TABLE VI*a*

Monthly and Seasonal Precipitation, 1887–1914, in Inches

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal
1887–88	0.01	.	0.40	.	0.76	2.94	5.84	1.92	4.50	0.20	0.42	0.50	17.49
1888–89	.0.0	.	0.59	0.02	2.71	3.79	0.78	0.54	7.58	0.72	1.50	0.06	18.29
1889–90	.	.	.	5.80	2.39	12.59	11.16	5.70	4.74	2.18	1.44	.0.0	46.00
1890–91	.	.0.0	0.25	.	.	3.32	1.13	10.68	3.17	3.42	1.61	0.38	23.96
1891–92	0.44	.	0.74	0.18	1.01	6.22	2.34	4.20	3.60	1.68	2.97	.	23.38
1892–93	.0.0	.0.0	0.07	1.99	5.35	6.64	3.90	3.28	6.19	1.62	0.26	.	29.31
1893–94	.	0.02	0.38	0.52	5.22	2.62	9.54	3.77	0.91	0.57	2.01	1.11	26.65
1894–95	.	.	1.61	3.29	1.35	12.63	10.88	3.25	2.64	2.30	1.06	.	39.01
1895–96	0.04	.	1.28	0.07	1.78	2.20	11.40	0.36	2.93	6.72	0.94	.	27.72
1896–97	.0.0	0.90	0.76	1.91	5.15	4.92	3.71	4.68	5.97	0.44	0.20	0.30	28.94
1897–98	.	.	0.20	2.48	1.58	2.71	1.54	3.28	0.31	0.19	1.87	0.24	14.40
1898–99	.	0.04	0.93	1.88	0.97	1.22	5.90	0.22	13.19	1.56	1.70	0.05	27.66
1899–1900	.	.0.0	.	5.26	5.85	3.46	4.18	1.02	3.00	1.58	0.91	0.08	25.34
1900–01	.	0.02	0.05	1.41	5.04	1.83	5.86	5.91	0.91	3.06	1.02	.	25.11
1901–02	.0.0	0.03	1.30	0.68	3.16	1.48	1.36	10.47	4.17	1.55	1.69	.	25.86

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Seasonal
1902–03	.	.0.0	.	2.35	3.21	3.69	5.17	2.05	7.81	1.11	0.02	.0.0	25.41
1903–04	.	.	.	0.50	5.89	2.19	1.40	10.45	10.80	2.10	0.02	.0.0	33.59
1904–05	.	0.07	4.44	3.39	2.23	2.03	5.58	2.56	4.25	1.37	3.43	.	29.35
1905–06	.	.	.	.0.0	1.46	2.22	6.92	3.96	9.05	0.74	2.56	0.64	27.55
1906–07	.	0.04	0.17	.0.0	1.64	7.24	5.02	5.36	10.76	0.36	0.04	1.24	31.87
1907–08	.	.0.0	0.06	1.54	0.08	4.84	5.44	4.35	1.37	0.30	1.17	0.01	19.16
1908–09	.	.	0.09	0.98	1.83	2.62	13.11	9.26	3.64	0.02	.	.	31.55
1909–10	.	.	0.78	1.34	3.43	7.24	3.38	1.85	3.82	0.41	0.01	0.02	22.28
1910–11	.	.	0.06	0.60	0.87	1.80	15.99	4.05	5.17	1.56	0.27	0.04	30.41
1911–12	.0.0	.	.0.0	0.73	0.46	2.51	3.65	0.54	2.96	1.47	1.56	0.85	14.73
1912–13	.	.	1.46	0.70	3.89	1.62	3.78	0.64	1.98	0.57	0.99	.0.0	15.63
1913–14	0.19	0.03	.	0.36	5.88	6.98	12.74	3.98	0.99	1.33	0.62	0.48	33.58
Averages	0.03	0.04	0.58	1.41	2.71	4.21	5.99	4.01	4.69	1.45	1.12	0.22	26.46

NOTE.—In accordance with the recommendation of the International Meteorological Committee, absence of precipitation is indicated by a dot (.); a trace, amount too small to measure, by the symbol .0.0.

The precipitation for the year was considerably in excess of the average, the total for the season being 127 per cent of the average for the twenty-seven years. The seasonal rainfall for 1913–1914 is one of the largest recorded at Berkeley since the establishment of the station in 1886. The seasonal amount has been exceeded only in two years and equaled in one year, as is

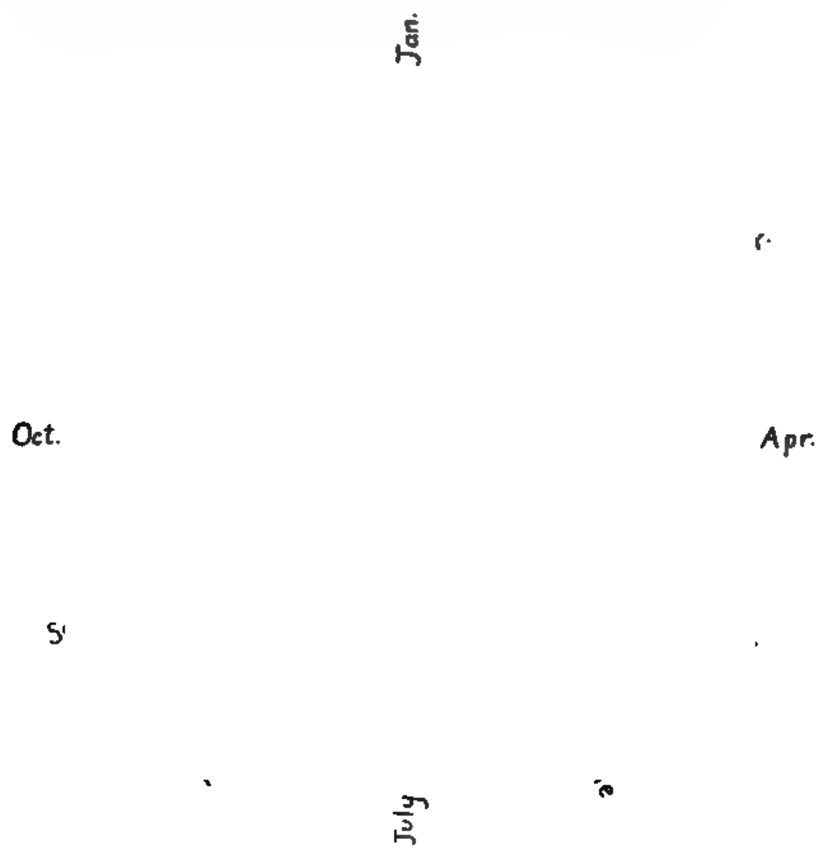


Fig. 5

shown by Table VII. There were several unusual conditions in the rainfall of the individual months of the year. Among these may be noted the occurrence of cyclonic rain in July and in August, the long dry period from August 29 to October 30, the excessive precipitation in November and in January, and the small amount in March.

TABLE VII

SEASONAL RAINFALLS AT BERKELEY, CALIFORNIA, EXCEEDING 800 MM., 31.50 IN., 1886–1914

Season	Precipitation Mm.	Precipitation In.
1889–90	1168.2	46.00
1894–95	991.0	39.01
1903–04	853.1	33.59
1908–09	801.5	31.55
1913–14	853.1	33.58

The rainfall of July, 4.8 millimeters, 0.19 inch, has been exceeded but once in the twenty-seven years, in 1891, when 11.2 millimeters, 0.44 inch, was recorded. There have been but five Julys with appreciable precipitation. The total precipitation for August, 1913, was less than the average for the twenty-seven years of record, but was more than usually occurs in August. The average for August is not a fair statement of the rainfall conditions; it is largely the result of a fall of 22.9 millimeters, 0.90 inch, in August, 1896. The amount for August, 1914, was exceeded only four times in the twenty-seven years and significant amounts have been recorded in only six Augusts, including 1914.

September and the first thirty days of October, 1914, were rainless. Rainless Septembers have been recorded six times in the twenty-seven years and rainless Octobers three times. In seven of the twenty-seven years there was a smaller amount of precipitation than in October, 1914.

The rainfall of November, 1914, 149.4 millimeters, 5.88 inches,

TABLE VIII

MONTHLY PRECIPITATION AT BERKELEY, CALIFORNIA, OF 300 MM., 11.81 IN., OR MORE, 1886–1914

Precipitation Mm.	Precipitation In.	Month
406.2	15.99	January, 1911
335.0	13.19	March, 1899
333.0	13.11	January, 1909
323.6	12.74	January, 1914
320.8	12.63	December, 1894
319.8	12.59	December, 1889

was more than twice the average for the month and was greater than that for any other November except that of 1903, when the precipitation was 149.6 millimeters, 5.89 inches. The amount for January, 1914, 323.6 millimeters, 12.74 inches, has been exceeded in only two Januarys and one March in the whole period of the record. Table VIII shows the months in which the precipitation equaled or exceeded 300 millimeters, 11.81 inches.

The accumulated rainfall to the end of each month is shown in Table IX, together with the monthly amounts, the average accumulated amounts and the departures from the average. This table gives a better idea of the manner in which the seasonal supply of water occurs than the other tables. The relations

TABLE IX

Monthly and Seasonal Precipitation for 1913–14, With Averages for Twenty-seven Years and Departures From the Averages

Month	Monthly		Seasonal to end of month		Average seasonal		Departure, 1913–1914	
1913	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
July	4.8	0.19	4.8	0.19	0.6	0.03	+ 4.2	+ 0.16
August	0.8	0.03	5.6	0.22	1.6	0.07	+ 4.0	+ 0.15
September	.	.	5.6	0.22	16.3	0.65	— 10.7	— 0.43
October	9.1	0.36	14.7	0.58	52.0	2.06	— 37.3	— 1.48
November	149.4	5.88	164.1	6.46	120.8	4.77	+ 43.3	+ 1.69
December	177.3	6.98	341.4	13.44	227.6	8.98	+113.8	+ 4.46
1914								
January	323.6	12.74	665.0	26.18	379.7	14.97	+285.3	+11.21
February	101.1	3.98	766.1	30.16	481.6	18.98	+284.5	+11.18
March	25.2	0.99	791.3	31.15	600.7	23.67	+190.6	+ 7.48
April	33.8	1.33	825.1	32.48	637.5	25.12	+187.6	+ 7.36
May	15.8	0.62	840.9	33.10	666.0	26.24	+174.1	+ 6.86
June	12.2	0.48	853.1	33.58	671.6	26.46	+181.5	+ 7.12
1913–14								
Season	853.1	33.58	853.1	33.58	671.6	26.46	+181.5	+ 7.12

between the conditions of 1913–1914 and the average of the period for which records are available are shown by figure 6, which is the accumulated departures of rainfall for the year 1913–1914. It is customary and probably substantially correct to consider the total amount of precipitation after the dry summer period as representing more or less accurately the available water supply for the season. There are, of course, losses, among

The number of thunderstorms during 1913–1914 was remarkable. The average number of thunderstorms in the region is small, not much more than one a year, and many years have been entirely without such storms. In 1913–1914 there were four thunderstorms recorded, two in January, one in February, and one in May. With the exception of the storm on the evening of January 25 none of the thunderstorms were at all severe and in most parts of the country this storm would be regarded as light. This was, however, the most severe in the twenty-seven years of the record. A building in Albany, about four kilometers, two miles, northwest of the University campus, was struck by lightning and burned. This storm occurred at about 21^{hrs} (9 P.M.), 120th meridian time; the other three storms occurred in the early morning hours, as is more usual in a west coast region.

Hail was reported on two dates with thunderstorms in January and May, and also on March 29, when thunder was not reported. In all three cases the hail occurred in the early morning hours between midnight and daylight. On January 18 hail also fell several times during the forenoon. Because of the relatively large number of days with thunderstorms and hail, the number of days with these phenomena has been added to Table II.

Days With Significant Precipitation

In Table X has been included the number of days in each month and in the year on which a significant amount of precipitation was recorded. Following the established custom, the number of days with precipitation equaling or exceeding 0.2 millimeter, 0.01 inch, and the number with precipitation equaling or exceeding 1.0 millimeter, 0.04 inch, have both been recorded. As was noted last year, this refers to gage catch, which may be slightly less than the true rainfall. There were 78 days when 0.2 millimeter was recorded, the largest number in a single month was 17 in November, the smallest was 0 in September; in all other months there was at least one day with measurable precipitation. During the year there were 64 days on which 1.0 millimeter was recorded, the largest number in any one month was 16 in January; there was no day on which 1.0 millimeter of precipitation was recorded in August or September.

TABLE X

NUMBER OF DAYS WITH 0.2 MM., 0.01 IN., OR MORE PRECIPITATION, BERKELEY, CALIFORNIA, 1887–1914

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
1887–88	1	0	3	0	8	8	13	8	12	4	4	5	66
1888–89	0	0	2	2	9	14	4	4	16	10	10	1	72
1889–90	0	0	0	12	8	24	21	14	16	5	4	0	104
1890–91	0	0	4	0	1	8	11	18	11	10	5	2	70
1891–92	2	0	6	2	4	12	9	10	11	8	10	0	74
1892–93	0	0	3	4	7	11	7	8	14	7	4	0	65
1893–94	0	1	3	3	10	11	12	11	7	3	7	3	71
1894–95	0	0	2	5	1	18	12	5	7	5	6	0	61
1895–96	1	0	4	5	7	9	15	3	11	14	6	0	75
1896–97	0	2	2	3	11	11	8	12	14	3	1	3	70
1897–98	0	0	3	5	7	6	9	9	3	1	6	3	52
1898–99	0	2	3	6	5	5	12	1	14	6	3	1	58
1899–1900	0	0	0	9	15	12	7	5	8	7	6	1	70
1900–01	0	1	2	7	8	4	13	13	3	5	5	0	61
1901–02	0	1	6	7	10	5	8	15	8	10	6	0	76
1902–03	0	0	0	6	6	11	10	5	16	5	1	0	60
1903–04	0	0	0	2	12	8	5	14	18	8	1	0	68
1904–05	0	1	0	3	6	9	10	5	11	5	3	0	53
1905–06	0	0	0	0	9	10	13	14	17	4	8	4	79
1906–07	0	2	1	0	7	11	12	9	18	2	1	3	66
1907–08	0	0	1	6	1	12	11	9	5	2	5	1	53
1908–09	0	0	1	3	4	7	25	15	10	1	0	0	66
1909–10	0	0	3	7	11	10	13	9	8	4	1	2	68
1910–11	0	0	1	2	4	3	17	11	9	4	2	2	55
1911–12	0	0	0	4	3	9	12	3	6	7	6	4	54
1912–13	0	0	3	5	10	6	13	8	5	5	5	0	60
1913–14	2	1	0	1	17	13	16	8	3	7	6	4	78
Averages	0	0	2	4	7	10	12	9	10	6	5	1	66

In figure 7 the average probability of days with significant precipitation (0.2 millimeter or more) at Berkeley is shown graphically for each month. This figure has been drawn to show, by reading from the top and using the scale of per cents at the right, the average probability of days without significant precipitation. The probability of days with significant precipi-

tation is shown in the figure by the shaded area. It will be noted that this shows practically the same features as the monthly rainfall shown by figure 5, which is to be expected, for in the long run the months with the greatest number of rainy days will be the months in which the precipitation is greatest.

The heaviest rainfall in twenty-four hours was 57.9 millimeters, 2.28 inches, for the twenty-four hours ending at 20^{hrs} (8 P.M.), January 12. This was the only time when the precipitation exceeded 50 millimeters, 2 inches, in twenty-four hours.

Fig. 7

The records refer to periods of twenty-four hours ending at the observation hours, as the record from the recording gage is not under the control of the station.

Cyclonic Rainfalls

In spite of the difficulties encountered in treating rainfall by cyclones, the importance of such treatment is so great that it is essential for a complete presentation of the climatic data of an extratropical station. These data have been compiled as Table XI. The method of compiling the data is similar to that employed in the report for 1913–1914, but it is believed that the separation of the cyclones has been more successful and that

TABLE XI

CYCLONIC RAINFALL, 1913–14

No.	Date	Precipitation Mm.	Precipitation In.	Barograph trace	Fall Mb.	Weather Map notes
1	July 22–23	4.8	0.19	Regular diurnal variation	....	Faint low over northern California, moving northeast
2	Aug. 26–28	0.8	0.03	Faint depression	5	Weak low over Great Valley, disappearing
3	Oct. 30–Nov. 1	33.0	1.30	Falling to noon Oct. 31, then unsettled	5	Low off Washington coast, moving eastward along the international boundary
4	Nov. 2–3	1.0	0.04	Flattening of diurnal variation	2(?)	Storm off Washington coast, a portion moving rapidly eastward; main storm remaining over ocean
5	Nov. 4–5	9.1	0.36	Slightly unsettled	....	Another portion of preceding storm moving rapidly across British Columbia
6	Nov. 5–8	2.3	0.09	Unsettled, small depression on the 7th	....	Strong low moving eastward across Washington Small low over northern California and Nevada, becoming a trough extending to Manitoba
7	Nov. 10–11	6.91	0.27	Moderate depression and irregularities	5	
8	Nov. 11–14	12.7	0.50	Marked depression	10	Moderate low off California coast, crossing Nevada and Arizona into northern Mexico
9	Nov. 17–18	35.8	1.41	Marked depression	10	Low off Columbia River, moving south into California and later off southern California coast
10	Nov. 19–21	15.0	0.59	Somewhat unsettled	....	Low off Vancouver, moving eastward across British Columbia
11	Nov. 23–27	31.0	1.22	Well marked depression with two minor depressions	10	Strong low crossing British Columbia
12	Nov. 28–30	11.7	0.46	Sharp depression and waves	8	Strong low crossing Washington
13	Dec. 9–11	5.3	0.21	Unsettled with moderate depression	3	Marked low moving eastward across British Columbia
14	Dec. 11–13	13.7	0.54	Marked depression	10	Storm over Pacific, moving southeast toward the Oregon coast and recurving to the ocean
15	Dec. 19–23	50.6	1.99	Unsettled until 21st, then marked depression	8	Storm off north Pacific Coast, moving southeast and crossing Nevada
16	Dec. 23–26	20.1	0.79	Marked depression	10	Moderate low off north Pacific coast
17	Dec. 28–Jan. 3	120.2	4.73	28th to 30th, unsettled with moderate depression; 30th to 1st, waves; 1st to 3rd, moderate depression with waves	7	Strong low off Vancouver; small portion passing eastward

No.	Date	Precipitation Mm.	Precipitation In.	Barograph trace	Fall Mb.	Weather Map notes
18	Jan. 6–8	13.2	0.52	Unsettled and moderate depression	5	Weak low crossing British Columbia
19	Jan. 10–13	58.7	2.31	Marked depression	13	Large low crossing northern Washington
20	Jan. 13–15	45.5	1.79	Weak depression	6	Moderate low crossing Washington
21	Jan. 15–19	50.0	1.97	Strong double depression	22	Large and severe storm crossing Oregon
22	Jan. 21–22	52.3	2.06	Marked fall	8	Large low crossing the north Pacific states
23	Jan. 23–28	71.4	2.81	23rd, falling (10 mb.); 24th, slight rise; 25th, fall (8 mb.); 26th–27th, low and and stationary; 27th–28th, rising	22	Large low shifting about Pacific coast; finally moving east across Washington
24	Feb. 16–22	100.8	3.97	Minor depression and unsettled, 16th–19th; 20th, marked depression	25	Large low off northern California coast, moving to Oregon and thence southeast
25	March 28–31	24.6	0.97	Moderate depression	8	Moderate low off Vancouver Island, moving east
26	April 3–5	14.7	0.58	Weak depression	7	Moderate low off north Pacific coast, crossing Washington
27	April 8–10	14.5	0.57	Unsettled with waves; weak depression	7	Moderate low off Washington coast, moving southeast to Arizona
28	April 20–23	3.3	0.13	Marked depression	12	Low over southern Nevada, moving eastward
29	April 26–28	1.3	0.05	Falling	7	Small low crossing British Columbia
30	May 7–8	5.3	0.21	Slight flattening of diurnal variation	2(?)	Conditons unsettled
31	May 13–16	1.3	0.05	Weak depression	7	Low trough extending from southern California to Oregon; moderate low breaking off at the north
32	May 20–25	9.1	0.36	Somewhat unsettled, slight general fall	3	Trough of low pressure lying over California, later moving northeast
33	June 5–7	9.7	0.38	Moderate depression	8	Moderate low off Washington coast, moving southeast
34	June 24	0.3	0.01	Faint depression	3	Moderate low over British Columbia, moving east
	Total cyclonic	850.0	33 46			
	Non-cyclonic	3.1	0.12			
		853.1	33.58			

meters, 0.01 inch, but traces of rain were observed twice with cyclonic cloud, although the barograph trace and weather maps did not clearly show cyclones. The average daily precipitation during the passage of cyclones varied from a maximum of 26.2 millimeters, 1.03 inch, in number 22, January 21 and 22, to a minimum of 0.3 millimeters, 0.01 inch, in number 31, May 13 to 16, and in number 34, June 24. The total number of days on which cyclonic conditions prevailed was 114, which makes the average amount of precipitation per day of cyclonic control 7.5 millimeters, 0.29 inch.

The duration of the cyclones was as varied as the rainfall. Subject to possible errors in the separation of cyclones when one closely follows another, the maximum duration of a single cyclone at Berkeley was seven days; there were two cyclones of this length, number 17, December 28 to January 3, and number 24, February 16 to 22. The minimum duration of a cyclone with significant precipitation was twelve hours, cyclone number 34, June 24.

An attempt has been made to show the relations indicated by Table XI graphically. Plates 47 to 55 show the relations of particular cyclones.[13] It is not proposed at this time to discuss each cyclone of the year, but merely to indicate typical cyclones as they control the precipitation at Berkeley. A careful study of all the cyclones which have influenced the weather of the station during an entire year or for a longer period from all available data, including barograms from other stations and the monthly average maps, such as are published in the *Monthly Weather Review*, will greatly increase our knowledge of the most important factor in the weather control of the middle latitudes. For the Berkeley station a beginning has been made, a partial result of which is the maps and curves of this report.

The nine cyclones selected from the thirty-four of the year have each had something particular to commend them to consideration. For the most part, each was accompanied by a more than moderate amount of precipitation, with the exception of

[13] This method of showing cyclonic data was devised by Professor W. M. Davis of Harvard University; see Rept. 8th Int. Geog. Congress, Washington, 1904, House Doc. 460, 58th Congress, 3rd Session (Washington, 1905), p. 286.

are to a great extent controlled by the local condition and in many cases do not represent the general circulation of the cyclones.

The plates include besides the weather maps copies of the barograph trace at Berkeley, the amounts of precipitation and the times at which precipitation occurred as far as known. The barograph trace has been copied directly without correction for pressure or clock errors, except that a general adjustment of the curve on the sheet has been made so that the errors are in part

Fig. 8

distributed and compensated; these curves are intended to show the general character of the pressure change and not the details of pressure at the station.

The storms which cause rainfall at Berkeley are practically all cyclones from the Pacific Ocean, rain from the Sonoran type being very rare at this station. The paths of the barometric centers of the cyclones of 1913 1914 have been plotted from the weather maps and are shown in figure 8. The relative number of cyclones which followed each path is shown by the width of the line, but all tracks north of the International Boundary have been generalized as a single track; and, as is necessary from the nature of the information, all tracks are much generalized. Most

TABLE XII

RAINFALL BY RAINFALL DAYS, 1913–14

(The rainfall day ends at 20hrs (8 P.M.) 120th Meridian time)

Cyclone No.	Date		Precipitation Mm.	In.	Cyclone No.	Date		Precipitation Mm.	In.
1	July	22	2.3	0.09	21	Jan.	17	40.4	1.59
		23	2.5	0.10			18	5.1	0.20
2	Aug.	27	0.8	0.03			19	4.6	0.18
3	Oct.	31	9.1	0.36	22		21	22.9	0.90
	Nov.	1	23.9	0.94			22	29.5	1.16
4		2	0.5	0.02	23		23	10.4	0.41
		3	0.5	0.02			24	33.5	1.32
5		4	9.1	0.36			25	21.8	0.86
		5	0.2	0.01			26	4.8	0.19
6		6	2.0	0.08			27	0.8	0.03
7		10	3.3	0.13	24	Feb.	16	0.8	0.03
8		11	3.6	0.14			17	2.0	0.08
		12	6.1	0.35			18	16.0	0.63
		13	3.8	0.15			19	12.2	0.48
9		18	35.6	1.40			20	45.5	1.79
10		19	0.2	0.01			21	9.6	0.38
		20	15.0	0.59			22	14.7	0.58
11		24	5.3	0.21	XX		25	0.3	0.01
		25	0.3	0.01	XX	Mar.	1	0.5	0.02
		27	25.4	1.00	25		29	23.9	0.94
12		29	11.7	0.46			30	0.8	0.03
13	Dec.	10	7.8	0.21	26	Apr.	4	14.7	0.58
14		11	0.8	0.03	27		8	1.8	0.07
		12	8.9	0.35			9	7.9	0.31
		13	4.1	0.16			10	4.8	0.19
15		19	4.8	0.19	28		21	1.5	0.06
		21	15.0	0.59			22	1.8	0.07
		22	25.4	1.00	29		27	1.3	0.05
16		23	5.3	0.21	30	May	8	5.3	0.21
		24	14.0	0.55	31		15	1.3	0.05
		25	6.1	0.24	32		22	2.0	0.08
17		29	14.5	0.57			23	3.3	0.13
		30	40.1	1.58			24	3.6	0.14
		31	33.0	1.30			25	0.2	0.01
	Jan.	1	6.6	0.26	33	June	6	8.4	0.33
		2	25.9	1.02			7	1.3	0.05
18		7	13.2	0.52	XX		19	2.3	0.09
19		12	57.9	2.28	34		24	0.3	0.01
20		13	9.1	0.36					
		14	37.1	1.46					
							Total,	853.1	33.58

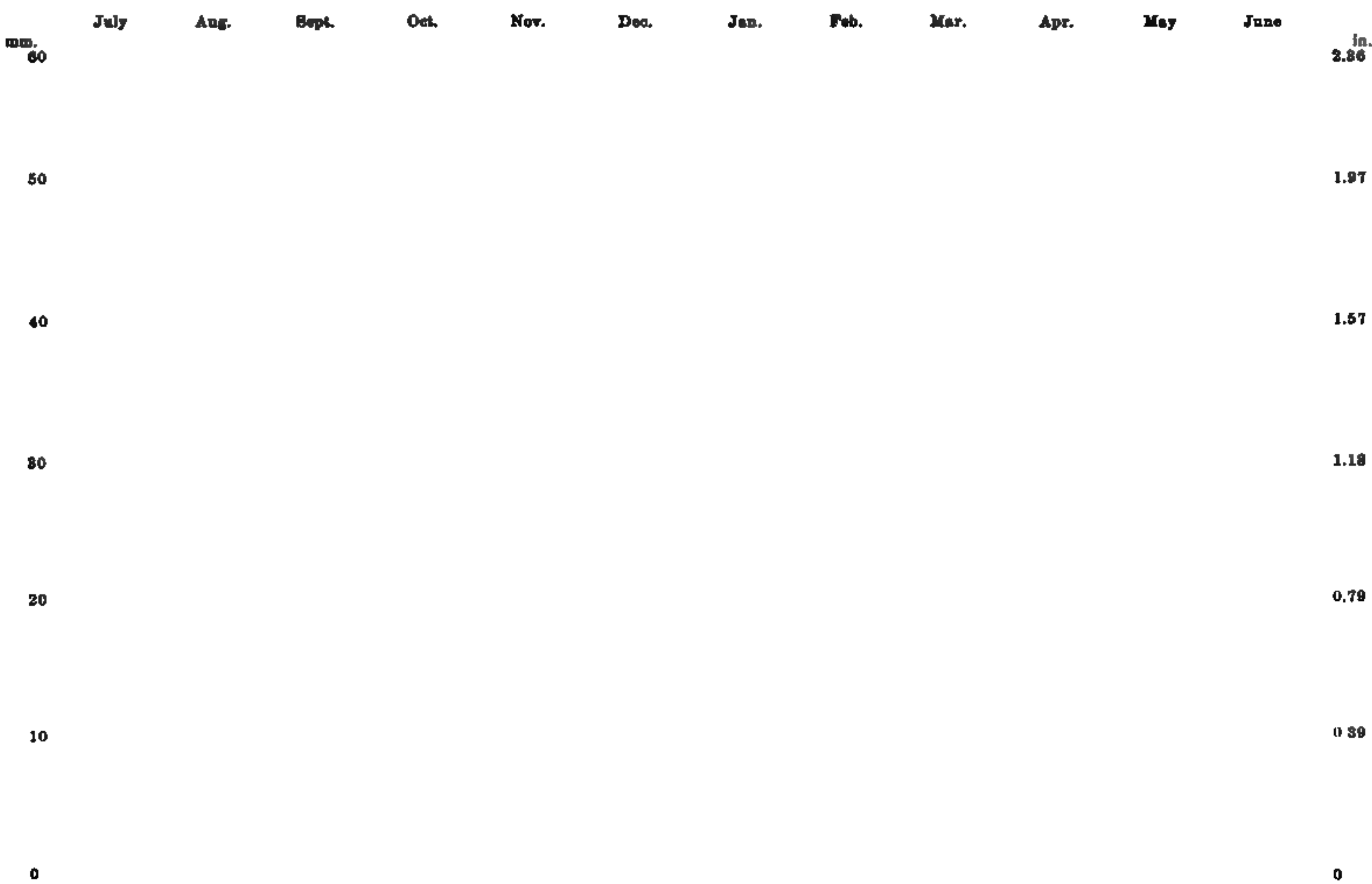


Fig. 9—Daily precipitation at Berkeley, California, 1913-1914

periods of several days together followed by periods without rain show very clearly the cyclonic character of the rainfall. The occurrence of the greater part of the rain in the winter months is also shown by figure 9, as is the comparatively dry summer. Noticeable also for the year 1913–1914 is the rainless period from August 28 to October 30 and the nearly rainless March. Another feature of the rainfall of Berkeley, which is shown more clearly by figure 9 than in any other way, is the occurrence of light rains during April, May, and June. While an examination of Table VI will show that the conditions during these months in 1914 was not quite the same as the average for the whole period of the record, the type of occurrence is the usual condition for the late spring at Berkeley.

WIND DIRECTIONS

Observations of wind directions have been made at the regular observation hours through the year from the drift of smoke and the direction of the flag on the campus. As was noted last year, the directions cannot be very accurate because of the absence of a vane and because of the fact that no accurate directions are laid down on the campus. The morning observations of wind direction are also probably better than the evening observations of this element. The daily prevailing winds summarized in Table I are the result of casual observations through the day, but probably represent with a fair degree of accuracy the prevailing winds at Berkeley.

The wind showed a marked tendency to blow from southerly directions at the observation hours in all months of the year; of the seven hundred and thirty observations of wind direction, four hundred and forty-six were from the southerly quadrant and of these two hundred and seventy-seven were from the south. The prevailing daily winds were from the southwesterly quadrant in all months except September. The details of the wind directions are best seen from Table I. The prevailing winds are shown by the wind-rose, figure 10.

The controls of wind at Berkeley were considered on pages 297 to 299 of the report for 1912–1913. The topography and the general and cyclonic pressure conditions are believed to exert the immediate controls.

Fig. 10

SUMMARY

The mean annual temperature at Berkeley for 1913–1914 was about 288° A, 58° F, with a mean annual range of 10° A, 17° F, and an extreme range of nearly 40° A, 70° F. The mean maximum temperature was 292° A, 67° F, and the mean minimum 283° A, 49° F. The mean monthly range was 22° A, 40° F, the mean daily range 10° A, 18° F. September was the warmest month of the year and December the coldest; no month had a very unusual temperature except March, which was in many respects a characteristic summer month. Frosts occurred from November to March.

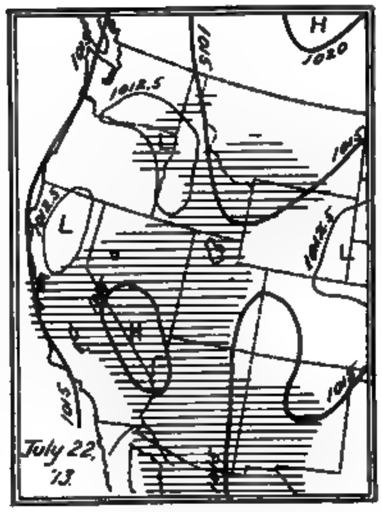
The pressure of the water vapor of the atmosphere was in general less than 15 millibars, 11.2 millimeters, or 0.42 inch of mercury, the relative humidity averaged 86 per cent morning and night, the mean dewpoint was about 280° A, 44° F, in the winter and about 285° A, 54° F, in the summer months. The vapor pressure and the dewpoint showed a strong tendency to vary with the air temperature. Nearly 40 per cent of the days were generally clear and nearly 30 per cent generally cloudy; many of the partly cloudy days, especially in summer, had several hours of bright sunshine. Fog was observed on twenty-nine days and the velo cloud, "high fog," on about as many more; this is not abnormal for Berkeley.

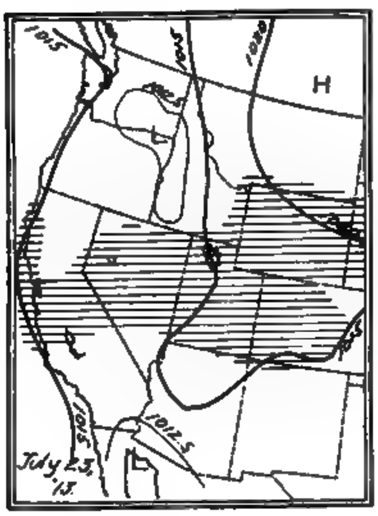
The total precipitation for the year was 853.1 millimeters, 33.58 inches, which is 181.5 millimeters, 7.12 inches, more than the average. September, October, March, and May had less than the average rainfall for these months, August, February, and April had about the average amount, and the other months had more than the average of the twenty-seven years of record. The precipitation of January was among the heaviest monthly rainfalls ever recorded at Berkeley. Thunderstorms were observed on four dates; on three days hail fell. There were seventy-eight days with significant precipitation, 0.2 millimeters or more, which is more than the average. In six months of the year there were more than the average number of rainy days for these months, and in six there were less than the average number. The heaviest fall of rain in a single day was 57.9 millimeters, 2.28 inches, on January 12; this is the only day on which as much as fifty millimeters, two inches, fell. The precipitation of the year was mainly the result of thirty-four cyclones, the barometric centers of most of which passed far north of Berkeley, although the cyclones were the controlling factors in the precipitation here; in many other cases the weather control was distinctly cyclonic.

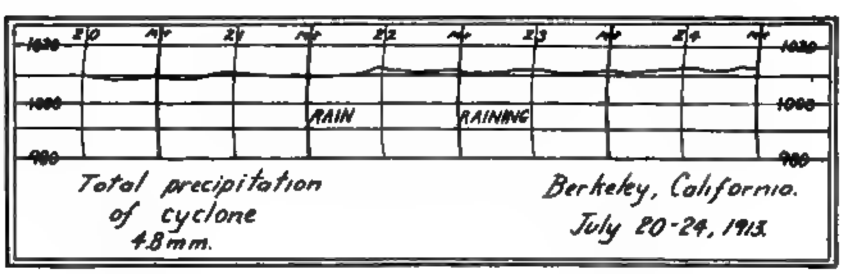
The wind was generally from southerly and southwesterly directions during the year. This is true both for prevailing winds and for the direction at the observation hours. The westerly element was more marked in the summer months. Calm days were rare, four during the year, but at more than one-third of the observation hours no air movement was recorded.

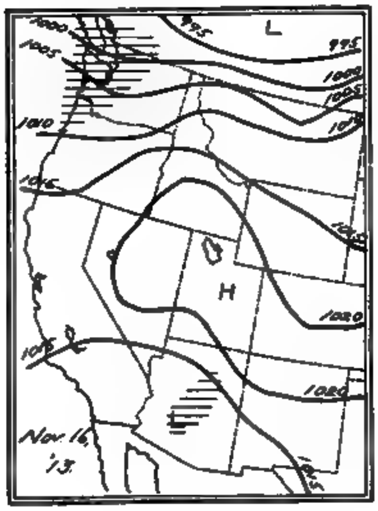
Transmitted December 3, 1914.

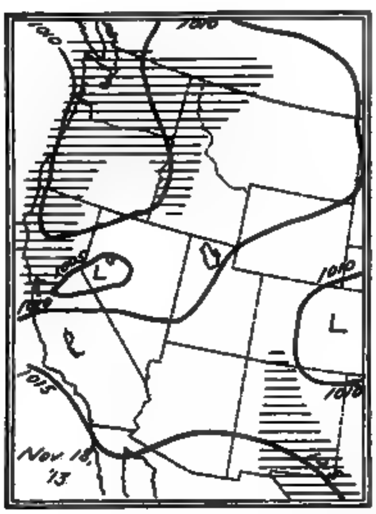

July 21,
'13.

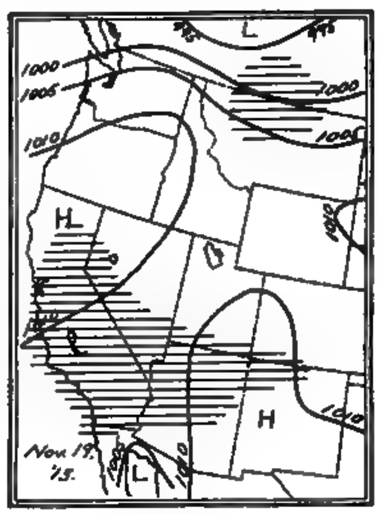

July 22,
'13.

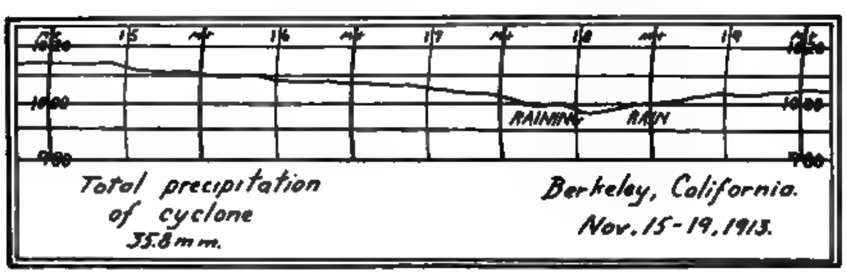

July 23,
'13.

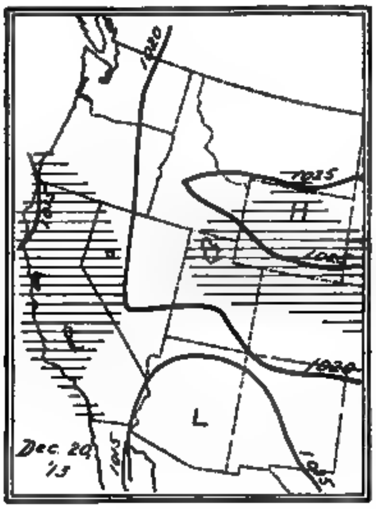

RAIN
RAINING
Total precipitation
of cyclone
4.8 mm.
Berkeley, California.
July 20-24, 1913.

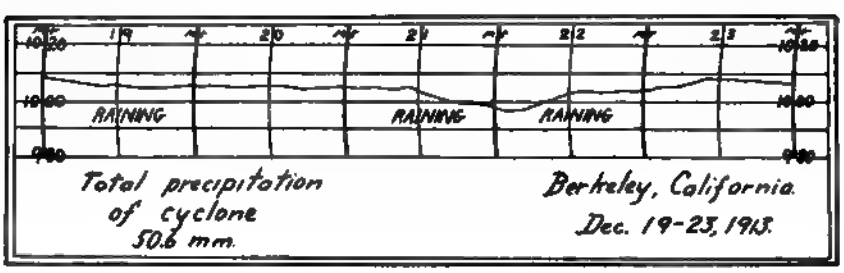

Nov. 16, '13.
L
H
995
1000
1005
1010
1015
1020

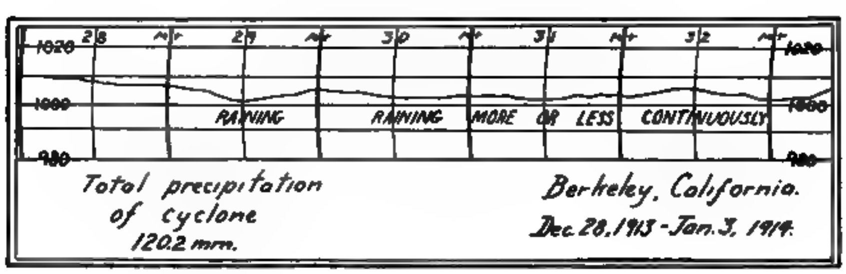

Nov. 18, '13.
L
1000
1010
1015

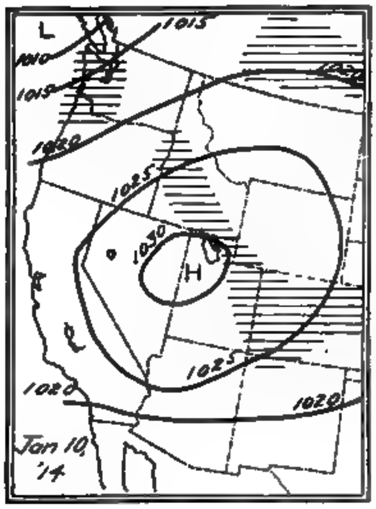

Nov. 19, '13.
L
H
995
1000
1005
1010

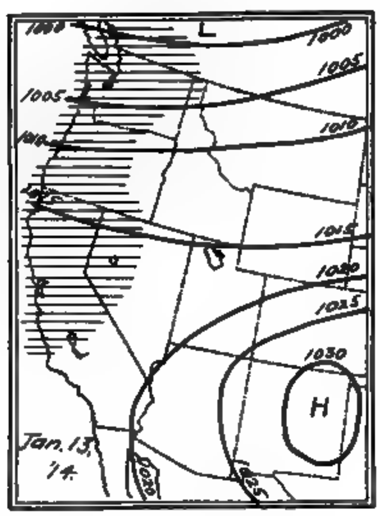

15
16
17
18
19
RAINING
RAIN
Total precipitation of cyclone 35.8 mm.
Berkeley, California.
Nov. 15-19, 1913.

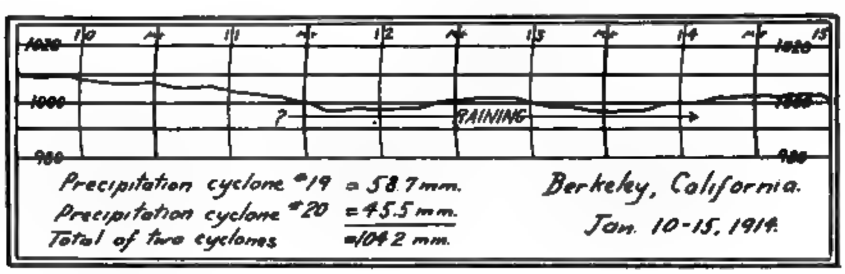

1020
1025
H
1020
L
Dec. 20
'13

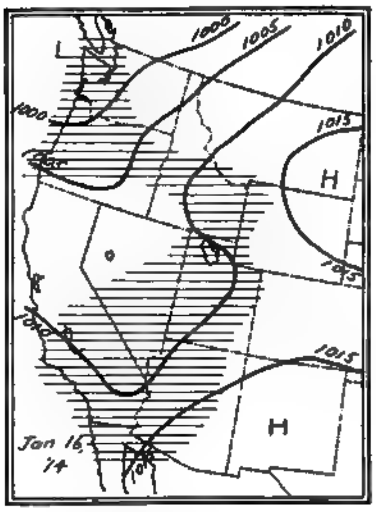

19
20
21
22
23
1020
1000
980
RAINING
RAINING
RAINING
Total precipitation
of cyclone
50.6 mm.
Berkeley, California.
Dec. 19-23, 1913.

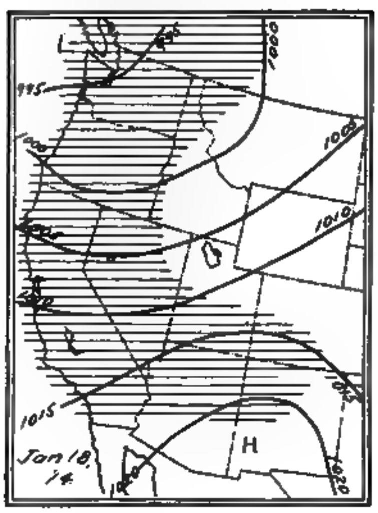

1020
1000
980
RAINING
RAINING MORE OR LESS CONTINUOUSLY
Total precipitation of cyclone 120.2 mm.
Berkeley, California.
Dec. 28, 1913 - Jan. 3, 1914.

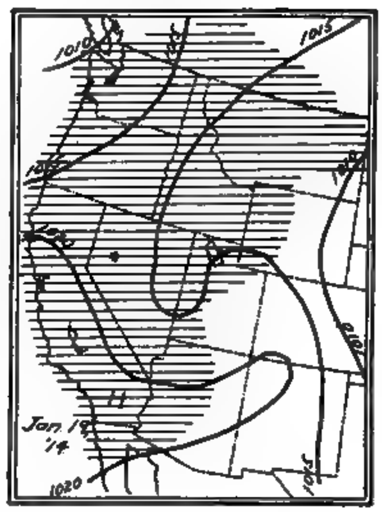

L
1015
1010
1015
1020
1025
1030
H
1025
1020
1020
Jan 10, '14

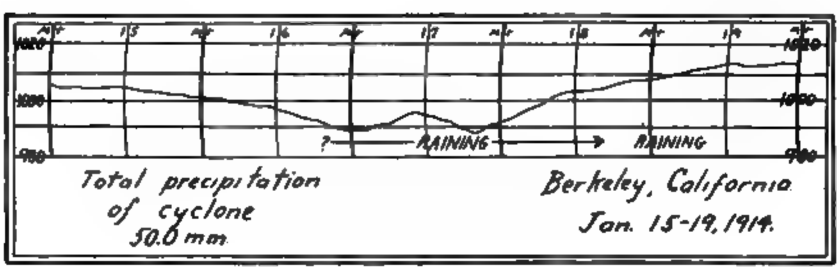

L
1000
1005
1005
1010
1010
1015
1020
1025
1030
H
1020
1025
Jan. 13, '14

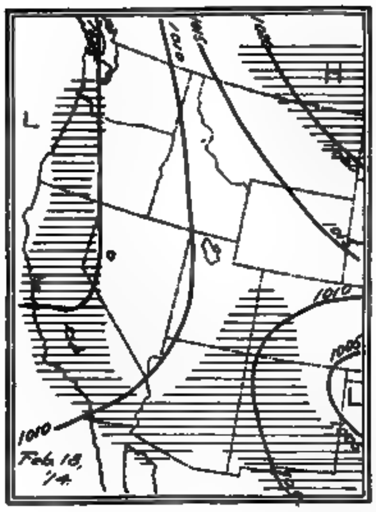

1020
1000
980
10
11
12
13
14
15
RAINING
Precipitation cyclone #19 = 58.7 mm.
Precipitation cyclone #20 = 45.5 mm.
Total of two cyclones = 104.2 mm.
Berkeley, California.
Jan. 10-15, 1914.

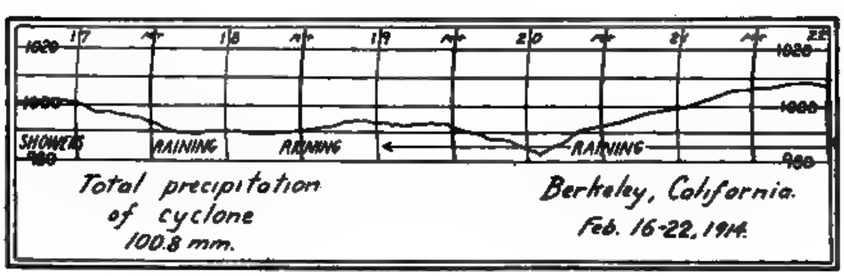

1000
1005
1010
1015
H
1015
H
Jan 16, '14

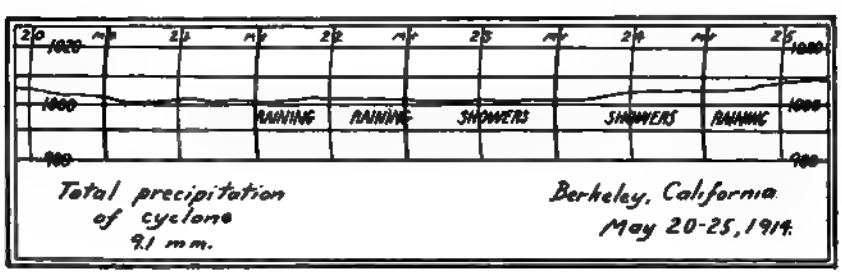

995
1000
1005
1010
1015
H
1020
Jan 18, '14


1010
1015
1020
Jan 19, '14


RAINING
RAINING
Total precipitation
of cyclone
50.0 mm
Berkeley, California
Jan. 15-19, 1914.


L
H
1010
1000
L
1010
Feb. 18, '14


17
18
19
20
21
22
1020
1000
980
SHOWERS
RAINING
RAINING
RAINING
Total precipitation of cyclone 100.8 mm.
Berkeley, California.
Feb. 16-22, 1914.


RAINING
RAINING
SHOWERS
SHOWERS
RAINING
Total precipitation
of cyclone
9.1 mm.
Berkeley, California
May 20-25, 1914.

UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
GEOGRAPHY
Vol. 1, No. 10, pp. 441-504, 14 text figs. February 28, 1917

REPORT

OF THE

METEOROLOGICAL STATION AT BERKELEY, CALIFORNIA

FOR THE

YEAR ENDING JUNE 30, 1915

BY

WILLIAM GARDNER REED

CONTENTS

I. STATION REPORT

INTRODUCTION

The work of the Meteorological Station maintained by the University of California was carried on by the Department of Geography during the year ending June 30, 1915. A complete statement of the history of the station and of the instruments and exposures was published in the reports for the years ending June 30, 1913,[1] and June 30, 1914.[2] The station has continued under obligations to Professor A. O. Leuschner and to various officials of the United States Weather Bureau, especially District Forecaster George H. Willson, Section Director for California. It is appropriate to record the writer's obligation to Professor R. S. Holway for his sympathetic and intelligent interest in the problems and activities of the station.

INSTRUMENTS AND EXPOSURES, 1914–1915

The instrumental equipment in service at the station during the year was as follows:

Maximum and minimum thermometers, United States Weather Bureau (Negretti and Zambra) pattern. Two exposures.

Wet and dry bulb thermometers, United States Weather Bureau "exposed" thermometers, mounted as stationary psychrometers. Two exposures.

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[1] Univ. Calif. Publ. Geog., vol. 1, no. 6, pp. 247–306, April 7, 1914.

[2] Univ. Calif. Publ. Geog., vol. 1, no. 9, pp. 373–439, April 10, 1916.

Richard thermograph, B. C. M. pattern, weekly record.

Richard hair hygrograph, standard size, weekly record.

Mercurial barometer, Fortin cistern, United States Weather Bureau pattern (Green), mounted in Weather Bureau barometer box.

Aneroid barograph, standard size, weekly record (Short and Mason).

Eight-inch rain-gage, United States Weather Bureau pattern.

The exposures of the preceding year were unchanged during 1914–1915. The barometer and barograph exposure is in the Geography Laboratory in the southwesterly corner of the ground floor of Bacon Hall; the elevation of the cistern of the mercurial barometer is 98.04 meters, 321.65 feet, above sea-level.[3] The cistern is about three-quarters of a meter above the floor, which is the ground-level. The thermometers, thermograph, and hygrograph are exposed in a shelter of the Weather Bureau co-operative observer's pattern at the Students' Observatory. This exposure is described on page 250 of the report for 1912-1913.

Observations and Records, 1914–1915

Observations have been made at the same hours as formerly, that is, at 8^{hrs} and 20^{hrs}, mean civil time of the 120th meridian west from Greenwich, which is 16^{hrs} and 4^{hrs} Greenwich mean civil time (8 A.M. and 8 P.M., Pacific Standard time). The regular observations were as follows:

1. Temperature of the air from the dry-bulb thermometer.
2. Temperature of evaporation from the wet-bulb thermometer.
3. Maximum temperature in the preceding 12 hours.
4. Minimum temperature in the preceding 12 hours.
5. Pressure of the air from the mercurial barometer.
6. Amount of cloud and the weather, from estimates.
7. Wind direction and estimated velocity.
8. Precipitation in the preceding 12 hours.

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[3] For a complete description of the elevation of the station see the Report for the year ending June 30, 1913, p. 250. Univ. Calif. Publ. Geog., vol. 1, no. 6, April 7, 1914.

In addition to the regular observations of measurable phenomena at the stated hours, a record has been kept of the general character of the day and the prevailing wind direction from casual observations made from time to time during the day. The times of beginning and ending of precipitation have been noted and recorded, and the occurrence and character of fog and frost have been recorded. The attempt to record miscellaneous phenomena of interest has been continued, in spite of the fact that such a record must be incomplete in the absence of more frequent observations than are usually practicable at the University. The autographic records of pressure, temperature, and relative humidity are complete for the year and are accurate for the exposures except for the errors inherent in the instruments, which are not large. For each month in which the tipping-bucket rain-gage was in operation at the Civil Engineering Building data were furnished by the Department of Civil Engineering.

The work of the station was carried on under the immediate direction of the writer until June 11, 1915; after this date Donald E. Martin was in charge until the end of the administrative year, June 30. The programme of observations and the computation and publication of the results, except for June, were under the writer's personal supervision. The following observers are responsible for the record during the periods stated:

July 1 to August 15, J. E. Krueger.

August 15 to December 15, Paul L. Fussell.

December 15 to January 15, J. E. Krueger.

January 15 to May 10, Paul L. Fussell.

May 10 to June 30, Donald E. Martin.

Occasional observations were made by other observers, especially C. W. Ray, E. W. McComas, and the writer. The original record on file in the Bancroft Library of the University of California shows the observer responsible for each observation. The writer is responsible for all decisions regarding policies and methods of observation and computation. For the most part the suggestions of the International Meteorological Committee and the regulations of the United States Weather Bureau have been followed.

REPORTS AND PUBLICATIONS, 1914–1915

The reports of the station during the year were the same as previously. The regular form of co-operative observer's report has been prepared for the Weather Bureau and sent to the office at San Francisco at the end of each month. This report includes the daily maximum and minimum temperatures, the amount and duration of precipitation, the prevailing wind and general character of each day, and a record of miscellaneous phenomena. The following printed summaries have been issued during the year:

Monthly Meteorological Synopsis of Berkeley, 2nd series, vol. 3, no. 1, July, 1914, to no. 12, June, 1915.

Monthly and Annual Meteorological Summary of Berkeley, University of California Chronicle, vol. 16, pp. 105–106, Berkeley, 1915.

Monthly and Seasonal Meteorological Summary of Berkeley, *ibid.*, vol. 16, pp. 311–312, Berkeley, 1915.

The following papers, embodying results of the work of the station, were published during the year:

The Climate of California, by William Gardner Reed. Calif. Mag., vol. 1, pp. 148–154, San Francisco, 1915.

Climatic Provinces of the Western United States, by William Gardner Reed. Bull. Am. Geog. Soc., vol. 47, pp. 1–15, New York, 1915.

Note on the Effects of Rain-Gage Exposure, by William Gardner Reed. Mo. Weather Rev., vol. 43, pp. 318–321, Washington, 1915.

The Water Resources of Strawberry Creek, Berkeley, California, by William Gardner Reed and Howard M. Loy. Mo. Weather Rev., vol. 43, pp. 35–39, Washington, 1915.

The following papers were prepared during the year, or as a result of the year's work, but not published until later:

Rainfall Data of Berkeley, California, by William Gardner Reed. Univ. Calif. Publ. Engin., vol. 1, no. 5, pp. 69–81, Berkeley, August 14, 1915.

Rainfall Data of Berkeley, California, II, by William Gardner Reed and Marshall K. White, Univ. Calif. Publ. Engin., vol. 1, no. 6, pp. 83-116, Berkeley, April 10, 1916.

Rainfall Data of Berkeley, California [a revised summary of the foregoing papers], by William Gardner Reed. Mo. Weather Rev., vol. 44, pp. 123–127, Washington, 1916.

Report of the Meteorological Station at Berkeley, California, for the year ending June 30, 1914, by William Gardner Reed. Univ. Calif. Publ. Geog., vol. 1, no. 9, pp. 373–439, Berkeley, April 10, 1916.

II. BERKELEY METEOROLOGY, 1914–1915

INTRODUCTION

The monthly and annual meteorological summary of Berkeley for the year ending June 30, 1915, appears as table I of this report. The summary is similar to those in the previous reports issued since the station came under the supervision of the Department of Geography in 1912. The use of the rational meteorological units of the C. G. S. system[4] has been continued and the English equivalents are also stated. Extracts from the monthly reports which have appeared during the year in the *Meteorological Synopsis of Berkeley* will be found immediately after table I.

For facilitating a comparison between the meteorological conditions of 1914–1915 and the average conditions since the establishment of the station, table II has been prepared. This table shows in rational and English units the summary for the whole period of observations at Berkeley, that is, since July 1, 1887, for pressures, mean and extreme temperatures, precipitation, and character of the day. Observations referring to 8^{hrs} and 20^{hrs} mean civil time of the 120th meridian west from Greenwich (8 A.M. and 8 P.M., Pacific Standard time) began with September 1, 1892, and means depending upon these observations are computed from that date.

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[4] These rational units are referred to absolute and not to gravity standards. The units are as follows:

PRESSURE, the *bar*, which is equal to an accelerating force of one *megadyne* (1,000,000 *dynes*) per square centimeter; the *bar* is divided into 1000 *millibars*, in which units the pressures in this report are expressed; 1000 *millibars* is a pressure equivalent to a column of mercury 29.53 inches in length under standard conditions. The millibar used in this report is the same as the kilobar of the Blue Hill system.

TEMPERATURE, the zero of this system, is 273 Centigrade degrees below the melting-point of pure ice; it is within a fraction of a degree of the absolute zero; the melting-point of pure ice is therefore 273° A, and the boiling-point of pure water under standard conditions is 373° A.

PRECIPITATION, the *millimeter*, which is one one-thousandth of the standard meter of the metric system; 1.0 *millimeter* equals 0.0393 inches.

For a bibliography see the previous reports of the Berkeley Station. See also McAdie, A. G., "Introduction of New Units at Blue Hill Observatory," Annals Harvard College Obs., vol. 73, pp. 85–90, Cambridge, 1915.

A careful consideration of air temperatures indicated that statements of fractions of degrees have a fictitious rather than a real value under many exposure conditions. This is particularly true at Berkeley, where conditions of air movement may easily change the temperature of a given spot by a degree Centigrade while an observation is being made; in addition, the ventilation within the shelter is far from perfect. The temperatures are therefore stated to the nearest whole degree. The responsibility for this rather drastic change in the statement of the data rests solely upon the writer. The decision was made under conditions which rendered a conference on the matter impracticable, but it is believed that temperature data to whole degrees represent the conditions at Berkeley more accurately than data to tenths of degrees, as was the practice heretofore.

The location of the instruments has been adequately described in the previous reports and no changes were made during the year. Reference may be made to these reports for descriptions of instruments and exposures.[5]

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[5] Report for 1912–1913, Univ. Calif. Publ. Geog., vol. 1, no. 6, pp. 247-306, Berkeley, April 7, 1914; Report for 1913–1914, *ibid.*, vol. 1, no. 9, pp. 373–439, Berkeley, April 10, 1916.

TABLE I—ABSOLUTE (CGS) UNITS

Summary of Observations at Berkeley, California, for the Year Ending June 30, 1915

Latitude +37° 52′. Longitude 122° 16′ west from Greenwich. Height of barometer cistern above sea, 98 meters
Height of thermometers above ground, 1.5 meters. Height of rain-gage above ground, 4.6 meters.
Observations at 8^{hrs} and 20^{hrs} Mean Civil Time of the 120th Meridian west from Greenwich (16^{hrs} and 4^{hrs} Greenwich Mean Civil Time)

Atmospheric Pressure (Sea-Level Equivalents) in Millibars

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air pressure (24 hrs.)	1016.6	1015.9	1015.5	1015.8	1019.0	1016.2	1017.3	1015.6	1018.4	1015.7	1015.0	1014.2	1016.3
Maximum air pressure[1]	1019.9	1021.0	1023.3	1023.3	1027.1	1027.7	1029.5	1030.8	1028.7	1023.8	1023.3	1024.3	1030.8
Date	22	27	3	10	19	14	9	4	14	8	26	20	Feb. 4
Hour (Civil time, 120th Meridian)	9	9	24	10	9	9	24	10	19	10	22	12½	10
Minimum air pressure[1]	1010.5	1010.5	996.6	1009.4	1002.7	1003.3	990.8	991.2	1006.4	1005.0	1003.3	1007.1	990.8
Date	15	6	12	3	30	16	29	2	28	30	1	3	Jan. 29
Hour (Civil time, 120th Meridian)	19	18	19	18	21	21	13	3	5	24	3	18	13

Air Temperature (in Absolute Degrees)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air temperature[2]	289	289	290	290	287	281	282	284	287	287	287	288	287
Mean air temperature at 8^{hrs}	286	287	288	287	283	279	280	282	284	285	287	289	285
Mean air temperature at 20^{hrs}	286	286	287	287	285	281	282	282	285	285	286	287	285
Mean maximum temperature[3]	293	293	295	295	294	285	286	287	292	291	291	295	291
Mean minimum temperature[4]	284	285	284	284	281	278	278	280	281	282	282	283	281
Highest daily mean[2]	291	292	296	296	292	287	285	285	294	290	294	295	296
Date	14	1	10	14	8	22	30	25	21	1	27	8	Sept. 10, Oct. 14
Lowest daily mean[2]	286	285	287	286	282	279	280	280	283	283	282	286	279

TABLE I—(*Continued*)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Date	2	30	2	2	30	15	15	21	1	30	2	18	Dec. 15
Maximum temperature[3]	299	300	307	306	301	293	290	290	303	298	302	303	307
Date	14	1	10	14	8	22	22	25	22	9	27	3	Sept. 10
Hour (120th Meridian)[5]	12	13	15	14	14	14	15	15	15	15	10	16	15
Minimum temperature[4]	283	283	282	280	278	274	275	276	278	279	278	282	274
Date	11	30	12	22	30	8	17	21	2	30	2	14	Dec. 8
Hour (120th Meridian)[5]	4	4	5	7	3	7	7	2	6	6	2	4	7
Monthly range	16	18	25	26	23	19	14	14	25	18	24	21	20
Mean daily range	9	9	11	11	13	8	8	7	11	9	9	12	10
Greatest daily range	16	17	23	21	18	12	12	12	17	16	16	18	23
Date	14	1	10	13	19	23	18	13	21	9	21	2 & 9	Sept. 10
Least daily range	7	4	2	3	7	3	3	2	3	5	2	5	2
Date	2	27	15	1	27	2	28	1	30	16	10	18	May 10
Mean change from day to day	1	1	2	2	1	1	1	1	1	1	2	1	1

Moisture

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean dew point at 8^{hrs}, ° A[6]	285	285	284	284	280	277	279	281	282	283	285	287	283
Mean dew point at 20^{hrs}, ° A[6]	286	285	286	284	281	279	279	281	283	284	284	286	283
Mean vapor pressure at 8^{hrs}, mb.[6]	14.1	14.2	13.4	13.0	10.3	8.4	9.9	10.5	11.7	12.1	14.2	16.0	12.3
Mean vapor pressure at 20^{hrs}, mb.[6]	14.3	14.1	12.5	12.9	10.6	9.4	9.7	11.1	12.2	12.9	13.3	14.9	12.3
Mean relative humidity at 8^{hrs}, %[6]	91	89	83	83	84	87	92	92	90	90	89	88	89
Mean relative humidity at 20^{hrs}, %[6]	93	93	80	83	75	87	80	85	90	94	92	92	89
Mean cloudiness at 8^{hrs}	.9	.8	.6	.4	.2	.4	.6	.6	.4	.6	.5	.3	.5
Mean cloudiness at 20^{hrs}	.7	.6	.2	.3	.2	.3	.5	.6	.4	.5	.4	.3	.5
Total precipit. (rain, dew, fog), mm.	.0.0	.	0.5	21.3	10.9	167.1	176.8	207.8	46.5	21.6	133.6	.	786.1
Max. precipitation in 24 hrs., mm.	.0.0	.	0.5	15.5	5.6	43.7	23.9	33.0	18.8	13.5	37.3	.	43.7
Date	11	.	7	16	1	17	8	8	28	26	11	....	Dec. 17

TABLE Ia—ENGLISH UNITS

SUMMARY OF OBSERVATIONS AT BERKELEY, CALIFORNIA, FOR THE YEAR ENDING JUNE 30, 1915

North Latitude 37° 52′. Longitude west from Greenwich 122° 16′. Height of barometer cistern above sea, 322 feet
Height of thermometers from ground, 5 feet. Height of rain-gage above ground, 15 feet
Observations at 8 A.M. and 8 P.M. Pacific Standard (120th Meridian) Time

Atmospheric Pressure (in Inches of Mercury) Reduced to Standard Gravity and Sea-Level

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air pressure (24 hrs.)	30.02	30.00	29.99	30.00	30.09	30.01	30.04	29.99	30.07	29.99	29.97	29.95	30.01
Maximum air pressure[1]	30.12	30.15	30.22	30.22	30.33	30.35	30.40	30.44	30.38	30 22	30.22	30.25	30.44
Date	22	27	3	10	19	14	9	4	14	8	26	20	Feb. 4
Hour (Pacific time)	9 a.m.	9 a.m.	Mt.	10 a.m.	9 a.m.	9 a.m.	Mt.	10 a.m.	7 p.m.	10 a.m.	10 p.m.	Noon	10 a.m.
Minimum air pressure[1]	29.83	29.87	29.43	29.81	29.61	29.63	29.26	29.27	29.72	29.68	29.63	29.74	29.26
Date	15	6	12	3	30	16	29	2	28	30	1	3	Jan. 29
Hour (Pacific time)	7 p.m.	6 p.m.	7 p.m.	6 p.m.	9 p.m.	9 p.m.	1 p.m.	3 a.m.	5 a.m.	Mt.	3 a.m.	6 a.m.	1 p.m.

Air Temperature (in Fahrenheit Degrees)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air temperature[2]	60	61	62	62	58	47	49	51	56	57	57	59	57
Mean air temperature at 8 a.m.	55	57	58	57	51	43	45	48	52	54	57	61	53
Mean air temperature at 8 p.m.	56	56	58	58	54	46	48	49	53	53	55	58	54
Mean maximum temperature[3]	68	69	72	72	70	54	56	58	66	65	65	72	66
Mean minimum temperature[4]	52	53	52	52	46	40	41	44	47	48	49	50	48
Highest daily mean[2]	65	66	73	73	66	57	54	54	70	62	70	71	73
Date	14	1	10	14	8	22	30	25	21	1	27	3	Sept. 10, Oct. 14
Lowest daily mean[2]	56	53	58	55	45	45	45	44	50	51	49	55	44
Date	2	30	2	2	30	15	15	21	1	30	2	18	Feb. 21
Maximum temperature[3]	79	81	94	91	82	67	62	63	85	76	89	85	94

TABLE Ia—(*Continued*)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Date	14	1	10	14	8	22	22	25	22	9	27	3	Sept. 10
Hour (Pacific time)[5]	Noon	1 p.m.	3 p.m.	2 p.m.	2 p.m.	2 p.m.	3 p.m.	3 p.m.	3 p.m.	3 p.m.	10 a.m.	4 p.m.	3 p.m.
Minimum temperature[4]	50	49	49	45	40	33	36	37	40	44	41	48	33
Date	11	30	12	22	30	8	17	21	2	30	2	14	Dec. 8
Hour (Pacific time)[5]	4 a.m.	4 a.m.	5 a.m.	7 a.m.	3 a.m.	7 a.m.	7 a.m.	2 a.m.	6 a.m.	6 a.m.	2 a.m.	4 a.m.	7 a.m.
Monthly range	30	32	45	47	41	34	26	26	45	33	43	37	36
Mean daily range	16	16	20	20	23	14	15	13	19	17	16	22	17
Greatest daily range	29	30	41	38	32	22	22	22	31	29	30	33	41
Date	14	1	10	13	19	23	18	13	21	9	21	29	Sept. 10
Least daily range	12	7	12	6	12	5	5	4	5	9	3	9	3
Date	2	27	15	1	27	2	28	1	30	16	10	18	May 10
Mean change from day to day	1	2	3	3	3	2	2	2	3	2	3	2	3

Moisture

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean dew point at 8 a.m., ° F[6]	54	54	52	52	45	40	43	46	48	50	54	57	50
Mean dew point at 8 p.m., ° F[6]	55	54	50	51	46	42	43	47	50	51	52	55	50
Mean vapor pressure at 8 a.m., in.[6]	.415	.417	.394	.384	.303	.247	.291	.309	.344	.356	.420	.474	.364
Mean vapor pressure at 8 p.m., in.[6]	.421	.416	.369	.381	.314	.268	.286	.328	.360	.380	.392	.441	.363
Mean relative humidity at 8 a.m., %[6]	91	89	83	83	84	87	92	92	90	90	89	88	89
Mean relative humidity at 8 p.m., %[6]	93	93	80	81	75	87	86	95	90	94	92	92	89
Mean cloudiness at 8 a.m.	.9	.8	.6	.4	.2	.4	.6	.6	.4	.6	.5	.3	.5
Mean cloudiness at 8 p.m.	.7	.6	.2	.3	.2	.3	.5	.6	.4	.5	.4	.3	.5
Total precipit. (rain, dew, fog), in.	.0.0	.	0.02	0.84	0.43	6.58	6.96	8.18	1.83	0.85	5.26	.	30.95
Maximum precipitation in 24 hrs.	.0.0	.	0.02	0.61	0.22	1.72	0.94	1.30	0.74	0.53	1.47	.	1.72
Date	11	....	7	17	1	17	8	8	28	26	11	....	Dec. 17

TABLE I AND Ia

Weather (Number of Days)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Clear	8	7	15	19	22	14	11	6	15	9	14	22	162
Partly cloudy	18	15	10	5	5	3	4	7	5	8	5	7	92
Cloudy	5	9	5	7	3	14	16	15	11	13	12	1	111
Days with fog[7]	1	4	5	1	3	1	1	0	2	2	1	7	28
Days with frost	0	0	0	0	0	11	3	0	0	0	0	0	14
Days with thunderstorms	0	0	0	0	0	0	0	1	0	0	0	0	1
Days with hail	0	0	0	0	0	0	0	1	0	0	0	0	1
Days with precipit $\geq$ 0.2 mm., .01 in.	0	0	1	4	4	14	17	19	9	5	14	0	87
Days with precipit $\geqq$ 1.0 mm., .04 in.	0	0	0	2	4	14	16	16	8	5	10	0	75
Longest period with precipitation	0	0	1	2	3	6	7	5	6	2	6	0	11
Longest period without precipitation	31	31	22	11	25	5	6	4	12	8	7	30	74[8]

Wind at 8^{hrs} and 20^{hrs} (Number of Observations)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
North	0	1	0	1	9	7	12	7	0	4	3	1	45
Northeast	0	0	1	3	1	6	8	5	7	9	1	0	41
East	0	0	6	6	6	3	2	4	5	5	1	0	38
Southeast	15	6	5	5	5	18	11	14	16	2	6	7	110
South	28	22	14	16	10	8	11	8	12	9	9	6	153
Southwest	5	21	9	9	6	9	7	9	9	15	10	10	119
West	8	4	9	3	7	4	1	5	2	6	24	29	102
Northwest	2	3	1	1	2	5	7	4	2	6	4	1	38
Calm	4	5	15	18	8	2	3	0	9	4	20	6	94

TABLE I AND I*a*—(*Concluded*)

Prevailing Wind (Number of Days)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
North	0	0	0	0	2	1	6	0	0	0	1	1	11
Northeast	0	0	0	0	2	1	6	1	1	1	0	0	12
East	0	0	1	2	3	2	2	0	0	0	2	0	12
Southeast	0	0	2	1	4	10	6	10	5	1	3	1	43
South	0	1	16	13	4	4	6	4	10	3	4	6	71
Southwest	16	17	8	8	7	8	2	9	11	9	9	6	110
West	15	11	3	6	2	1	3	2	3	12	9	16	83
Northwest	0	2	0	1	6	4	0	2	1	3	3	0	22
Calm	0	0	0	0	0	0	0	0	0	1	0	0	1

[1] From barograph corrected for pressure and clock errors.

[2] ½ (maximum + minimum).

[3] From Negretti and Zambra type maximum thermometers, mercury in glass.

[4] From Rutherford type minimum thermometers, alcohol in glass.

[5] From thermograph corrected for temperature and clock errors.

[6] From stationary psychrometer, wet and dry bulb thermometers.

[7] Includes only days on which fog lay on the campus. See *Internationaler Meteorologischer Kodex*, ed. 2, Berlin, 1911, p. 18: "Fog is to be recorded only when the observer is enveloped in it."

[8] From the beginning of the summer rainless period, June 25, 1914.

TABLE II—ABSOLUTE (CGS) UNITS

SUMMARY OF OBSERVATIONS AT BERKELEY, CALIFORNIA, JULY 1, 1887, TO JUNE 30, 1915

CONSTANTS OF THE STATION

(International Symbols)[1]

From	ϕ	λ	H Meters	H_b Meters	h_t Meters	h_r Meters	Hours of observation: Civil Time 120th Meridian	Hours of observation: G.M.T. (Civil)
July 1, 1887	+37° 52′	122° 16′ W	102.4	96.6	2.1	6.4	7, 14, 21	15, 22, 5
Sept. 1, 1892	+37° 52′	122° 16′ W	96.3	96.6	2.1	0.3	8, 20	16, 4
Oct. 1, 1899	+37° 52′	122° 16′ W	100.6	96.6	2.1	4.6	8, 20	16, 4
July 1, 1912	+37° 52′	122° 16′ W	100.6	98.0	1.5	4.6	8, 20	16, 4

Atmospheric Pressure (Sea-Level Equivalents) in Millibars

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air pressure	1013.5	1013.5	1013.8	1015.9	1018.2	1018.2	1019.0	1018.6	1017.2	1016.9	1015.2	1013.8	1016.2
Maximum air pressure[2]	1023.3	10.21.3	1022.6	1025.7	1044.0	1032.4	1035.5	1033.2	1031.2	1031.2	1026.4	1024.3	1044.0
Date and observation	12, I	21, II	3, 24 hrs.	25, II	13, IV	25, II	7, II	8, II	11, I	15, II	21, II	20, 12 hrs.	12/25, II
Year	1888	1900	1914	1893	1895	1903	1913	1899	1888	1895	1893	1914	1903
Minimum air pressure[2]	1001.7	1001.0	996.6	998.0	992.8	996.9	990.8	988.8	989.8	989.8	1001.7	998.3	988.8
Date and observation	19, IV	4, IV	13, IV	20, III	18, 13 hrs.	22, I	29, 13 hrs.	22, V	8, V	28, V	25, II	3, II	Feb. 2, V
Year	1893	1893	1913	1889	1913	1888	1915	1891	1891	1901	1906	1893	1891

Air Temperature (in Absolute Degrees)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air temperature[3]	289	289	290	289	286	282	282	283	284	286	287	289	286
Mean air temperature at 8^{hrs}	288	287	287	286	283	280	280	281	282	284	286	288	284
Mean air temperature at 20^{hrs}	288	288	289	287	285	282	282	281	284	284	286	288	286
Mean daily maximum temperature[4]	294	294	295	292	290	285	285	287	286	290	292	294	290
Mean daily minimum temperature[5]	285	285	286	284	281	279	279	280	280	281	283	284	282

TABLE II—(*Continued*)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Highest daily average[3]	299	301	302	299	296	289	294	294	297	295	298	296	302
Date	2	26	16	8	16	18	26	18	17	12	26	29	Sept. 16
Year	1903	1894	1913	1899	1895	1893	1899	1899	1914	1898	1896	1891	1903
Lowest daily average[3]	285	285	285	283	277	276	273	275	277	280	282	283	273
Date	18	6	3	23	27	20	15	14	3	19	15	6	Jan. 15
Year	1903	1887	1903	1899	1896	1908	1888	1899	1896	1896	1894	1914	1888
Maximum temperature[4]	309	307	314	308	301	294	298	299	304	293	307	312	314
Date	7	22	16	1	16	24	26	18	17	24	26	6	Sept. 16
Year	1905	1891	1913	1913	1895	1901	1899	1899	1914	1913	1896	1903	1913
Minimum temperature[5]	279	281	281	277	274	272	269	271	274	275	277	279	269
Date	29	21	28	18	28	24	14	12	30	19	1	2	Jan. 14
Year	1899	1905	1905	1905	1895	1905	1888	1905	1905	1896	1899	1903	1888
Mean monthly range	19	17	21	21	17	20	16	17	19	21	19	21	19
Mean daily range	9	8	9	9	7	6	6	7	8	9	9	10	8
Mean change from day to day	1	1	1	2	1	1	1	1	1	1	1	2	1

Moisture

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean dew point at 8^{hrs}, °A[6]	285	286	285	284	281	279	278	279	280	282	284	285	282
Mean dew point at 20^{hrs}, °A[6]	286	286	286	285	282	280	280	281	281	282	284	285	283
Mean vapor pressure at 8^{hrs}, mb.[6]	14	15	14	13	11	9	10	9	16	11	13	14	12
Mean vapor pressure at 20^{hrs}, mb.[6]	15	15	15	14	12	10	10	11	11	12	13	14	13
Mean relative humidity at 8^{hrs}, %[6]	87	88	87	86	89	87	90	88	88	86	85	84	87
Mean relative humidity at 20^{hrs}, %[6]	85	87	85	84	84	85	83	86	87	86	86	85	85
Mean cloudiness at 8^{hrs}	.6	.7	.5	.4	.5	.4	.6	.5	.6	.5	.5	.5	.5
Mean cloudiness at 20^{hrs}	.5	.6	.4	.3	.4	.4	.4	.2	.4	.4	.4	.4	.4
Av. precipitation (all kinds), mm.	0.5	1.0	14.7	36.4	68.2	108.9	152.9	105.9	116.3	36.4	32.2	5.3	678.7
Most in a day, mm.	11.6	21.3	69.9	81.7	62.7	75.1	95.6	125.3	90.7	65.6	57.1	16.7	125.3
Date	9	29	23	20	20	2	15	12	13	24	1	17	Feb. 14
Year	1891	1896	1904	1899	1903	1892	1894	1904	1899	1896	1905	1894	1904

See notes 1-6 at foot of page 457.

TABLE IIa—ENGLISH UNITS

SUMMARY OF OBSERVATIONS AT BERKELEY, CALIFORNIA, JULY 1, 1887, TO JUNE 30, 1915

CONSTANTS OF THE STATION

(International Symbols)[1]

From	Latitude	Longitude	H Ft.	H_b Ft.	h_t Ft.	h_r Ft.	Hours of observation Pacific Time
July 1, 1887	37° 52′ N	122° 16′ W	336	317	7	21	7 a.m., 2 p.m. 9 p.m.
Sept. 1, 1892	37° 52′ N	122° 16′ W	315	317	7	1	8 a.m., 8 p.m.
Oct. 1, 1899	37° 52′ N	122° 16′ W	330	317	7	15	8 a.m., 8 p.m.
July 1, 1912	37° 52′ N	122° 16′ W	330	322	5	15	8 a.m., 8 p.m.

Atmospheric Pressure (in Inches of Mercury) Reduced to Standard Gravity and Sea-Level

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air pressure	29.93	29.93	29.94	30.00	30.00	30.07	30.09	30.08	30.04	30.03	29.98	29.94	30.01
Maximum air pressure[2]	30.22	30.16	30.22	30.29	30.49	30.83	30.58	30.51	30.45	30.45	30.31	30.25	30.83
Date and observation	12, I	21, II	3, Mt.	25, IV	13, IV	25, II	7, II	8, II	11, I	15, II	21, II	20, noon	12/25, II
Year	1888	1900	1914	1893	1895	1903	1913	1899	1888	1895	1893	1915	1903
Minimum air pressure[2]	29.58	29.56	29.43	29.47	29.30	29.44	29.26	29.20	29.23	29.23	29.58	29.48	29.20
Date and observation	19, IV	4, IV	13, 5 p.m.	20, III	18, 1 p.m.	22, I	29, 1 p.m.	22, V	8, V	28, IV	25, IV	8, II	Feb. 22, V
Year	1893	1893	1913	1889	1913	1888	1915	1891	1891	1901	1906	1893	1891

Air Temperature (in Fahrenheit Degrees)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean air temperature[3]	62	62	63	60	55	49	48	51	52	55	58	61	56
Mean air temperature at 8 a.m.	58	58	58	55	50	46	45	46	49	51	55	58	52
Mean air temperature at 8 p.m.	59	59	60	58	54	49	48	51	51	51	56	59	55
Mean daily maximum temperature[4]	70	69	70	68	62	55	53	57	55	63	66	70	62
Mean daily minimum temperature[5]	53	54	55	52	48	43	42	44	45	47	50	52	49
Highest daily average[3]	79	82	87	78	74	61	70	69	75	72	78	83	87
Date	2	26	16	8	16	18	26	18	7	12	26	29	Sept. 16
Year	1903	1894	1913	1899	1895	1893	1899	1899	1914	1898	1896	1891	1903
Lowest daily average[3]	54	54	53	49	40	37	32	36	39	45	50	51	32
Date	18	6	3	23	27	20	15	14	3	19	15	6	Jan. 15
Year	1903	1887	1903	1899	1896	1908	1888	1899	1896	1896	1894	1914	1888

TABLE IIa—(*Continued*)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Maximum temperature[4]	97	93	106	95	82	70	77	80	87	87	93	101	106
Date	7	22	16	1	16	24	26	18	17	24	26	6	Sept. 16
Year	1905	1891	1913	1913	1895	1901	1899	1899	1914	1913	1896	1903	1913
Minimum temperature[5]	42	46	46	39	33	27	25	29	34	36	40	42	25
Date	29	31	28	18	28	24	14	12	30	19	1	2	Jan. 14
Year	1899	1905	1905	1905	1895	1905	1888	1905	1905	1896	1899	1903	1888
Mean monthly range	34	31	37	38	31	36	28	31	34	37	34	38	34
Mean daily range	17	15	16	16	13	12	11	13	15	16	17	18	15
Mean change from day to day	2	2	2	3	2	2	2	2	2	2	2	3	2

Moisture

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean dew point at 8 a.m., ° F[6]	54	55	54	51	47	42	45	43	45	48	51	53	49
Mean dew point at 8 p.m., ° F[6]	55	56	55	53	49	44	44	46	47	49	52	54	50
Mean vapor pressure at 8 a.m., in.[6]	.42	.43	.42	.37	.32	.27	.30	.28	.30	.33	.37	.40	.34
Mean vapor pressure at 8 p.m., in.[6]	.43	.45	.43	.40	.35	.29	.29	.31	.32	.35	.39	.42	.36
Mean relative humidity at 8 a.m., %[6]	87	88	87	86	89	87	90	88	88	86	85	84	87
Mean relative humidity at 8 p.m., %[6]	85	87	85	84	84	85	83	86	87	86	86	85	85
Mean cloudiness at 8 a.m.	.6	.7	.5	.4	.5	.4	.6	.5	.6	.5	.5	.5	.5
Mean cloudiness at 8 p.m.	.5	.6	.4	.3	.4	.4	.4	.2	.4	.4	.4	.4	.4
Av. precipitation (all kinds), in.	0.02	0.04	0.58	1.43	2.68	4.29	6.02	4.16	4.59	1.43	1.27	0.21	26.72
Most in a day, in.	0.44	0.84	2.75	3.22	2.47	2.96	3.70	4.75	3.43	2.48	2.16	0.63	4.75
Date	9	29	23	20	20	2	15	12	13	24	1	17	Feb. 14
Year	1891	1896	1904	1899	1903	1892	1894	1904	1899	1896	1905	1894	1904

[1] The International Symbols are:
ϕ the latitude of the station.
λ the longitude from Greenwich.
H the altitude (rim of the rain-gage) above sea-level.
H_b the altitude of the barometer cistern above sea-level.
h_t the height of the thermometers above ground.
h_r the height of the rain-gage rim above ground.

[2] At the regular observation hours only until June 30, 1912, after this date from the barograph corrected for pressure and clock errors. Observation hours are indicated as follows: 7^{hrs}, 7 a.m., I; 8^{hrs}, 8 a.m., II; 14^{hrs}, 2 p.m., III; 20^{hrs}, 8 p.m., IV; and 21^{hrs}, 9 p.m., V.

[3] ½ (maximum + minimum).

[4] From Negretti and Zambra type maximum thermometers, mercury in glass.

[5] From Rutherford type minimum thermometers, alcohol in glass.

[6] From stationary psychrometer, wet and dry bulb thermometers.

TABLE II AND IIa

Weather (Number of Days)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
Clear	13	9	13	15	15	14	11	12	12	14	13	15	156
Partly cloudy	7	9	8	8	6	7	8	6	7	8	8	8	90
Cloudy	11	13	9	8	9	10	12	10	12	8	10	7	119
Days with fog[7]	12	11	7	4	4	2	2	3	2	2	2	5	56
Days with frost	0	0	0	0	4	8	8	4	3	0	0	0	27
With precipitation $\geqq$ 0.2 mm., .01 in.	0[8]	0[8]	2	4	7	10	11	9	10	6	5	1	67
With precipitation $\geqq$ 1.0 mm., .04 in.	0[8]	0[8]	1	3	5	8	10	8	9	4	3	1	52
Longest period with precipitation	2	2	5	4	8	12	11	8	11	5	5	5	16
Longest period without precipitation	31	31	30	31	28	22	22	25	26	24	31	31	221

Wind at 8^{hrs} and 20^{hrs} (Number of Observations)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year
North	1	1	2	4	5	7	4	5	6	5	3	1	44
Northeast	0	0	1	2	4	6	5	3	2	2	1	0	26
East	2	2	2	3	5	7	6	5	3	3	3	1	42
Southeast	3	5	5	5	5	7	9	6	6	3	4	5	63
South	16	17	10	8	7	6	9	8	10	9	11	14	125
Southwest	13	10	6	4	3	1	2	3	5	8	8	13	76
West	9	8	6	4	2	1	1	2	4	5	8	6	56
Northwest	2	1	2	3	3	2	3	2	4	5	4	2	33
Calm	16	18	26	29	26	25	23	22	22	20	20	18	265

[7] Probably includes days not strictly in accord with the international definition of days with fog. See *Internationaler Meteorologischer Kodex*, ed. 2, Berlin, 1911, p. 18: "Fog is to be recorded only when the observer is enveloped in it."

[8] The number of days with precipitation equal to 0.2 millimeter or more in the twenty-eight years of the record is 9 in July and 9 in August; the number of days with 1.0 millimeter or more is 3 in July and 3 in August.

EXTRACTS FROM THE MONTHLY REPORTS

JULY, 1914, was a month with a large amount of velo cloud ("high fog"); the number of days (22) was equaled in July, 1894, and July, 1895, but has never been exceeded. In many cases the cloud was very low, less than 30 meters, 100 feet, above the level of the campus, and it therefore was a true fog in the higher portions of Berkeley. It is probable that fog occurred on the campus during some of the nights other than the 15th, when fog was recorded. The occurrence of velo cloud at morning and night has resulted in a large number of partly cloudy days; the sky was generally clear during the daytime hours, except on the five days recorded as cloudy. Cloud other than the velo sheet was rare.

A trace of rain, probably during the early morning of the 11th, was the result of a weak barometric depression; at the same time San Francisco reported 0.5 mm., 0.02 in.

The mean temperature for the month was about 1 degree Absolute (2 degrees Fahrenheit) lower than the normal, and the maxima were generally low; but the record is not strictly homogeneous owing to a change in the exposure conditions in 1912. The summary of temperatures under the old exposure conditions is as follows: mean for the month, 289° A, 61° F; mean maximum, 293° A, 67° F; mean minimum, 285° A, 54° F; maximum, 298° A, 77° F, on the 14th, and minimum, 284° A, 51° F, on the 6th.

The prevailing wind directions were southwest and west, of moderate velocities. The wind directions at the observation hours are considerably influenced by the air drainage from Strawberry Cañon.

AUGUST, 1914, like July, was characterized by an excessive amount of velo cloud ("high fog"); the number of days with velo cloud (22) was exceeded in August, 1895, when twenty-five days were recorded, and equaled in August, 1893. In most cases the cloud sheet was very low during the night, and in the higher parts of Berkeley was a fog according to the definition of the International Meteorological Committee; fog in this sense occurred on the campus at an observation hour only on the morning of the 27th; fog also occurred on three nights. The velo cloud persisted through the day seven times during the month. Velo cloud was the only type of cloud recorded during the month; this cloud caused the high cloudiness at the observation hours and the large number of partly cloudy days. On several days when the sky was overcast at the observation hours there was a considerable amount of bright sunshine during the day.

No precipitation was collected by the rain-gage during the month, although at times the trees were dripping with water collected from the low cloud, and there was considerable precipitation around trees and bushes, especially on the hills.

The temperatures for the month were all slightly lower than the normal, although the air temperatures were not nearly as low as might have been inferred from the sensible temperatures, which were low be-

cause of the large amount of low cloud. Air temperatures were about the same as the air temperatures of July. The summary of temperatures under the old exposure conditions is as follows: mean for the month, 288° A, 59° F; mean maximum, 291° A, 64° F; mean minimum, 285° A, 54° F; maximum, 300° A, 80° F, on the 1st; minimum, 284° A, 52° F, on the 17th.

September, 1914, like the other two months of the season, was characterized by an unusual amount of fog and velo cloud. True fog occurred on the campus from the evening until the following forenoon on the 7th, 11th, 22nd, 23rd, and 24th, and velo cloud, which was a true fog in the higher parts of Berkeley, was observed on five other nights; in all cases this cloud lasted well into the morning.

Temperatures were not far from the averages for Berkeley. The maximum, 307° A, 94° F, was higher than has commonly occurred, although this record was exceeded in 1913, with a maximum of 318° A, 106° F; in 1912, with 311° A, 101° F; and in 1914, with 310° A, 99° F. That the high temperature was due to the freer exposure is shown by the fact that in the window shelter the maximum was 302° A, 85° F, on the 10th; the effect of the co-operative observer's shelter is also indicated by the occurrence of higher temperatures than previously in all three years since the station temperatures have been observed in this shelter. The maximum on the 10th was 5° A, 9° F, higher than the next highest maximum of the month.

The summary of temperatures from the window shelter is as follows: mean, 289° A, 61° F; mean maximum, 293° A, 68° F; mean minimum, 285° A, 53° F; maximum, 302° A, 85° F, on the 10th; and minimum, 283° A, 52° F, on the 2nd.

The precipitation, 0.5 mm., 0.02 in., occurred during a dense fog on the early morning of the 7th; this was not simply moisture collected from the fog, but the rain fell as a rather sharp shower for a considerable time. In addition to the velo cloud there was a cyclonic cloud in two periods during the month when cyclonic rain was falling in the northern states, although there was no precipitation at Berkeley.

October, 1914, was a month of generally clear skies and bright sunshine. Only one-sixth of the days were cloudy through the day. Temperatures were slightly higher than the average for October, although this is due largely to the change in exposure, as is shown by the following record from the window shelter: mean for the month, 288° A, 59° F; mean maximum, 292° A, 67° F; mean minimum, 284° A, 52° F; maximum, 300° A, 81° F, on the 14th; and minimum, 280° A, 45° F, on the 22nd. On several days during the month the minimum temperature for the day was recorded at the evening observation.

The highest temperatures and the greatest ranges of temperature occurred on the 13th and 14th, which had many of the characteristics of "north wind days," although the wind was generally southwesterly on both dates. Fog occurred on the evening of the 14th from about 21^{hrs}, 9 P.M., until the following morning.

The month was one of distinct cyclonic control. There were four periods in which cyclonic rain fell, as follows: the 1st and 2nd, 0.2 mm., 0.01 in.; the 7th to the 9th, 0.3 mm., 0.01 in.; the 16th to the 18th, 20.8 mm., 0.82 in.; and the 29th and 30th, trace. The barograph trace at other times shows distinct cyclonic conditions The Department of Civil Engineering has kindly furnished the following rainfall rates: maximum in 5 minutes, 1.3 mm., 0.05 in.; in 10 minutes, 2.0 mm., 0.08 in; in 15 minutes, 2.8 mm., 0.11 in.; in 30 minutes, 4.3 mm., 0.17 in.; in 1 hour, 5.3 mm., 0.21 in.; and in 2 hours, 8.4 mm., 0.33 in.

There was probably a greater amount of southerly wind than is usual in October, although the records of past years have not been critically examined.

NOVEMBER, 1914, was a month of rather high atmospheric pressure with generally clear skies and little rain. The number of clear days (22) has been exceeded but three times in the twenty-eight Novembers of the record. The temperatures from the thermometers in the window shelter show little departure from the normal. The record is as follows: mean for the month, 286° A, 55° F.; mean maximum, 290° A, 63° F; mean minimum, 281° A, 47° F; maximum, 295° A, 72° F, on the 8th; and minimum, 278° A, 41° F, on the 30th.

Tule fog was observed at the morning hour on the 12th and the 23rd, and at the evening hour on the 10th. In all cases the thickness upward was slight.

The rainfall for the month was less than 16 per cent of the normal for November. It occurred as the result of two rain periods: one on the 1st, when the fall was 5.6 mm., 0.22 in., and the other from the 27th to the 29th, when the fall was 5.3 mm., 0.21 in. A cyclone of considerable intensity began on the 30th; the pressure fell steadily more than 12 millibars, 0.36 in., in 11 hours, but rain did not begin until after 20^{hrs}, 8 P.M., the end of the rainfall day. The heavy fall of rain in the last four hours of the month belongs properly with that of the early days of December, and is so recorded. The Department of Civil Engineering reported that there were no rainfall rates of significant intensity during the month.

A brisk to high wind blew from the southeast through the day and evening of the 30th, but at all other times the velocity was moderate or low.

DECEMBER, 1914, was cold and rainy. The precipitation was about 56 per cent in excess of the average for the month. The amount has been exceeded six times in twenty-eight years. The following record of rainfall of marked intensity is reported by the Department of Civil Engineering: December 2, 8.4 mm., 0.33 in., fell in 60 minutes from $14^{hrs}\ 45^{min}$, 2.45 P.M.; December 6, 1.8 mm., 0.07 in., fell in 2 minutes from $13^{hrs}\ 32^{min}$, 1.32 P.M.; December 6, 2.5 mm., 0.10 in., fell in 5 minutes from $13^{hrs}\ 32^{min}$, 1:32 P.M.. December 16, 10.9 mm., 0.43 in., fell in 1 hour from $18^{hrs}\ 5^{min}$, 6:05 P.M.; December 16, 17.8 mm., 0.70 in., fell in 1 hour 50 minutes from $17^{hrs}\ 15^{min}$, 5:15 P.M.; December 16, 25.4 mm., 1.00 in., fell in 3 hours from $17^{hrs}\ 15^{min}$, 5:15 P.M.

The record of temperatures from the window shelter is as follows: mean for the month, 281° A, 46° F; mean maximum, 284° A, 52° F; mean minimum, 278° A, 40° F; maximum, 291° A, 65° F, on the 22nd; and minimum, 273° A, 32° F, on the 8th. The window shelter was the exposure during the greater part of the period from which the normals were deduced. The number of days with frost (14) has been exceeded but once, 1897; in three other Decembers frost was observed on thirteen days. It should be noted that the record of frosts is subject to considerable error because of the irregular topography of Berkeley and the variations in the deposit of frost under different conditions.

A strong, gusty wind of the "Santa Ana" type, carrying much dust, blew from the east and northeast for about twenty-four hours on the 23rd.

JANUARY, 1915, was characterized by a considerable amount of cloud and a large number of rainy days. The temperature conditions were slightly more uniform than is usual in January. The small amount of frost is the result of cloudiness. The amount of fog was small because of the cyclonic activity.

The record of temperatures from the window shelter is as follows: mean for the month, 281° A, 47° F; mean maximum, 284° A, 53° F; mean minimum, 278° A, 41° F; maximum, 288° A, 60° F, on the 28th; and minimum, 275° A, 35° F, on the 17th.

The total precipitation was about 16 per cent in excess of the average; this has been exceeded seven times in twenty-eight years in January, but the number of days with rain has been exceeded only twice and equaled once. Several flashes of lightning occurred about 19^{hrs}, 7 P.M., on the 11th.

The precipitation was the result of six more or less distinct cyclones. That from the 26th to the 30th produced a depression of the barograph trace larger and deeper than previously recorded at Berkeley, although there are a few records of lower air pressure at the station. The following rainfall of marked intensity is reported by the Department of Civil Engineering: January 3, 2.8 mm., 0.11 in., fell in 3 minutes from 17^{hrs} 47^{min}, 5:47 P.M.; January 3, 3.3 mm., 0.13 in., fell in 5 minutes from 17^{hrs} 47^{min}, 5:47 P.M.; January 5, 2.3 mm., 0.09 in., fell in 5 minutes from 20^{hrs} 10^{min}, 8:10 P.M.; January 5, 3.6 mm., 0.14 in., fell in 10 minutes from 20^{hrs} 10^{min}, 8:10 P.M.; January 8, 2.8 mm., 0.11 in., fell in 3 minutes from 16^{hrs} 56^{min}, 4:56 P.M.; January 8, 3.3 mm., 0.13 in., fell in 5 minutes from 16^{hrs} 54^{min}, 4:54 P.M.; January 8, 4.6 mm., 0.18 in., fell in 10 minutes from 16^{hrs} 49^{min}, 4:49 P.M.; January 8, 20.8 mm., 0.52 in., fell in 60 minutes from 16^{hrs} 40^{min}, 4:40 P.M.

FEBRUARY, 1915, was a cold, wet month. The temperatures from the standard shelter are not far from the normal, but the freer exposure is the cause of this. The record from the window shelter, which was the standard exposure for the first twenty-five years of the record, is as follows: mean for the month, 283° A, 50° F; mean maximum, 286° A, 55° F; mean minimum, 280° A, 44° F; maximum, 289° A, 59° F, on the 25th; and minimum, 276° A, 37° F, on the 21st.

The precipitation has been exceeded in only four Februarys in twenty-eight years, and the number of days with rain has never been equaled.

summer cloud. The temperature was somewhat higher than the average in both the standard and the window shelters. The summary from the window shelter is as follows: mean for the month, 286° A, 56° F; mean maximum, 290° A, 63° F; mean minimum, 283° A, 49° F; maximum, 296° A, 73° F, on the 9th; and minimum, 279° A, 43° F, on the 30th.

The precipitation for the month was mostly the result of showers; there was but one depression of the barograph trace of importance, from the 11th to the 16th, when but 3.0 mm., 0.12 in., of rain fell. The rest of the rain fell at times when the barograph trace showed only slight irregularities. At the end of the month there were irregularities and generally falling pressure which developed into a well marked depression May 1. The seasonal precipitation was 165.9 mm., 6.53 in., less than the amount to May 1, 1914, but slightly in excess of the average amount. The Department of Civil Engineering reports the following interesting rainfall intensities: April 25, 2.5 mm., 0.10 in., fell in 5 minutes from 20^{hrs} 30^{min}, 8:30 P.M.; 4.6 mm., 0.18 in., fell in 10 minutes from 20^{hrs} 30^{min}, 8:30 P.M.; 7.6 mm., 0.30 in., fell in 20 minutes from 20^{hrs} 25^{min}, 8:25 P.M.

True fog was recorded on the morning of the 1st and of the 2nd; that of the 1st became a very fine rain for a few minutes about 8^{hrs}, 8 A.M., but there was no water in the gage. The fog of the 2nd was less than 30 meters, 100 ft., in depth.

The prevailing wind directions were southwest and west. The wind velocities were light, except on the 13th, when a northwest wind of about 13 meters per second, 30 miles per hour, blew during the day, and on the 29th and 30th, when the velocity probably reached 20 meters per second, 45 miles per hour, in gusts.

MAY, 1915, was a rainy month. The total precipitation (133.6 mm., 5.26 in.) was the greatest May rainfall since the establishment of the station in October, 1886. The seasonal amount to June 1 was 119.9 mm., 4.72 in., above the normal. The amount to June 1, 1915, is 116.1 mm., 4.57 in., more than the average for the twelve months. This rainfall was the result of six more or less distinct cyclones.

The temperature of the month was about normal in both the standard and the window shelters. The summary for the window shelter is as follows: mean for the month, 287° A, 56° F; mean maximum, 290° A, 63° F; mean minimum, 283° A, 50° F; maximum, 296° A, 72° F, on the 27th; and minimum, 279° A, 42° F, on the 2nd.

True fog was recorded on the morning of the 16th and "high fog" on the 21st.

JUNE, 1915, was characterized by an unusually small number of cloudy days. Velo cloud ("high fog") was recorded on only five days. Because of the lack of cloud the maximum temperatures were somewhat higher and the minimum temperatures somewhat lower than the normal. The summary of temperatures from the window shelter is as follows: mean for the month, 287° A, 58° F; mean maximum, 289° A, 63° F; mean minimum, 284° A, 52° F; maximum, 296° A, 72° F, on the 3rd; minimum, 283° A, 50° F, on the 23rd.

No rain was recorded during the month. The total rainfall for the season was 786.1 mm., 30.95 in. This was 107.4 mm., 4.20 in., above the average for the twelve months.

The winds were in general light, although a few moderate to high winds were recorded.

ATMOSPHERIC PRESSURE

Observations

Pressure was measured twice daily, at 8^{hrs} and 20^{hrs}, mean civil time of the 120th meridian west from Greenwich; this is 16^{hrs} and 4^{hrs} Greenwich mean civil time, or 8 A.M. and 8 P.M., Pacific Standard time, the time in local use. The barometer in use is a Fortin cistern mercurial instrument of the United States Weather Bureau pattern. The mean monthly and annual pressures have been corrected for diurnal variation by a table furnished by the Weather Bureau.[6] The annual mean is one-twelfth of the sum of the monthly means. Sea-level equivalents have been given in all cases; these may be converted to station pressures by subtracting 12 millibars, 8.9 millimeters, or 0.35 inch of mercury, from the pressures stated in the tables, as the air temperature is so constant that the reduction is seldom different from this value. Station pressures were reduced to the sea-level equivalents by the use of the Bigelow reductions as adopted by the Weather Bureau.[7] The amount of the reduction is so small that the well-known objections to this system of reduction apply only in part and they are more than offset by the fact that the system is used by the United States Weather Bureau. However, the time will be welcomed when reductions may be made with better assurance of correctness or when a practicable method of using station pressures is devised.

Mean Air Pressures

The average pressure for the year 1914–1915 was 1016 millibars, 762 millimeters, or 30.01 inches, of mercury at standard gravity and the temperature of melting ice, which is practically

[6] Published as table III in the Report for 1913–1914, p. 402, Univ. Calif. Publ. Geog., vol. 1, no. 9, pp. 373–439, Berkeley, April 10, 1916.

[7] See Bigelow, F. H., "Report on Barometry in the United States, Canada, and West Indies," U. S. Weather Bur. Ann. Report, 1901, Washington, 1901; also Smithsonian Institution, Smithsonian Meteorological Tables, ed. 3, Washington, 1907.

the same as the average for the twenty-eight years of the record. The highest monthly average was that for November, 1019 millibars, 764 millimeters, or 30.09 inches; and the lowest was that for June, 1014 millibars, 761 millimeters, or 29.95 inches. Although pressure relations are doubtless of great importance as showing the character of the seasons in California, unfortunately no correlations have been made between monthly pressures and other meteorological conditions at Berkeley.

Table III shows the pressure departures for each month and the departures of mean daily and mean minimum temperatures and monthly precipitation. The most important thing shown by this table is the fact that there is no close and definite relation between the departures, or at least that no such relation is apparent from the 1914–1915 departures as given. November was a month of weak cyclonic conditions, but with generally high pressure. The average pressure for November, 1914, was the same as that of the highest monthly average for the full period of twenty-eight years, which is that of the month of January. The lowest monthly averages from the twenty-eight year record are those for July and August, but the June average is only 0.3 millibar, 0.3 millimeter, or 0.01 inch, higher. The average pressure for June, 1915, was only 0.4 millibar higher than the average of all the Junes since 1888. The June average was the lowest monthly average of the year 1914–1915.

EXTREME AIR PRESSURES

The highest pressure recorded during the year was 1031 millibars at 10^{hrs} on February 4. February, generally a month of considerable cyclonic activity, showed even greater pressure variations than usual. The total range in February, 1915, was 39.6 millibars, 30 millimeters, or 1.17 inches, which is only 0.4 millibar less than the annual range. The range in a single cyclone in February was 39.4 millibars. The highest pressure recorded at Berkeley prior to June 30, 1915, was 1044 millibars, 783 millimeters, or 30.83 inches, at 8^{hrs} on December 25, 1902; it is probable that the pressure rose two or three millibars higher to the time of diurnal maximum about two hours later, but this cannot be definitely stated, as there was no barograph at that station

TABLE III

Comparison of Departures From Twenty-Eight Year Averages, Berkeley, California, 1914–1915

Month 1914	Mean monthly pressure Millibars	Mean monthly temperature ° A	Mean minimum temperature ° A	Total monthly precipitation Millimeters
July	+3.1	±0	—1	— 0.5
August	+2.4	±0	±0	— 1.0
September	+1.7	±0	—2	— 14.2
October	—0.1	+1	±0	— 15.1
November	+0.8	+1	±0	— 57.3
December	—2.0	—1	—1	+ 58.2
1915				
January	—1.7	±0	±0	+ 23.9
February	—3.0	+1	+1	+101.9
March	—1.2	+3	+1	— 69.8
April	—1.2	+1	—1	— 14.8
May	—0.2	±0	—1	+101.4
June	+0.4	—1	—1	— 5.3
1914–1915				
Year	+0.6	±0	—1	+107.4

at that time. The absolute range in any month is 51 millibars, 38 millimeters, or 1.51 inches, for December.

The lowest pressure in the year ending June 30, 1915, was 990.8 millibars, 743 millimeters, or 29.26 inches, at 13hrs, 1 P.M., on January 29, during a cyclone which produced a depression

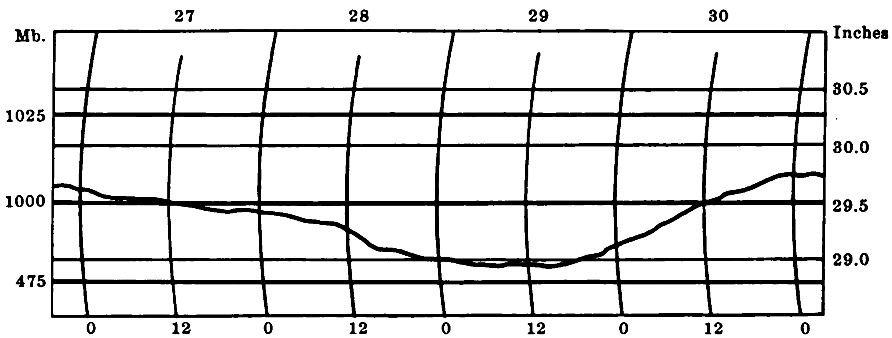

Fig. 1. Barographic trace at Berkeley, California, January 27–30, 1915.

of the barograph trace more marked than any previously recorded at Berkeley since the beginning of continuous pressure records in July, 1912; figure 1 is the trace for this cyclone, as recorded by the barograph. This pressure is one of the notable low pressures at Berkeley and is the lowest record for January. It

is not, however, the lowest pressure recorded at the station. The low record is 988.8 millibars, 741 millimeters, or 29.20 inches, which was recorded at 21^{hrs}, 9 P.M., on February 2, 1891, although this may not be the absolute minimum, as there was no barograph in operation at the station at that time. The January range was 38.7 millibars, 29 millimeters, or 1.14 inches, which is large even for a month of great cyclonic activity, such as January.

Pressure and Temperature

The relation between temperature and pressure does not appear close, as judged by the data for 1914–1915. The departures from the mean monthly and mean monthly minimum temperatures show very little similarity to the pressure departures. This information is contained in table III.

While it has not been practicable to determine the pressure conditions at times of very high or very low temperature at Berkeley, it may be noted that neither the minimum temperature and the maximum pressure, nor the maximum temperature and the minimum pressure, occurred on the same day in 1914–1915. In general, high temperatures occur with "north wind" conditions; these high temperatures result from strong insolation due to clear skies and low humidities, together with dynamic warming of rapidly moving and descending air. This condition is the result of high pressure over the Basin Region rather than of any particular pressure relations at Berkeley. Low pressures occurred at Berkeley during the passage of cyclones, and at such times the sky was overcast and rain falling, so that opportunities for strong insolation were wanting, and hence low pressures were not accompanied by high temperatures. In fact, it has been noted in California that there is a marked analogy between the pressure conditions resulting in the "north wind" and high temperatures and those permitting strong terrestrial radiation and hence low temperatures. The highest temperatures are apt to occur in the late summer, when the coast fog has ceased to be a factor, or in the early summer before the fog conditions have set in. The lowest temperatures have occurred during winter anticyclones.

TEMPERATURE

· Observations

Temperature data similar to those in the previous reports are included in table I, and a general summary of the temperature data of the whole period of the record appears in table II. Temperatures have been stated to the nearest whole degree, as this is as great accuracy as is warranted by the character of the information. The thermometers in use are probably able to show the temperature of the air inside the shelter with an accuracy ten times as great; but very small differences in the time of observation, in wind direction and velocity, in addition to the well-known difficulties in obtaining satisfactory thermometer exposure, make it probable that temperature data finer than whole degrees have no significance even for the conditions at the Students' Observatory. When a region such as the University campus is considered, to say nothing of the City of Berkeley, it is evident that even in the statement of averages accuracies greater than whole degrees Absolute are fictitious.

The change in exposure in the summer of 1912 makes comparison between the data for 1914–1915 and those of average temperatures for the whole period somewhat unsatisfactory, although it may be noted that the average difference between the temperatures shown by the thermometers in the two exposures is about one degree Absolute, two degrees Fahrenheit.

Mean Temperatures

Figure 2 shows the march of mean monthly, mean maximum, and mean minimum temperatures for 1914–1915; figure 3 is similar for the twenty-eight year averages. The heavy line in the middle shows the mean monthly temperatures, obtained from the mean of the daily maxima and the mean of the daily minima for each month. The upper line shows the means of the daily maxima, and the lower line those of the daily minima. All temperatures are from Weather Bureau pattern thermometers.[8]

The warmest months were September and October. The mean temperature for September was about the average, but October

[8] Maximum, Negretti and Zambra type, mercury in glass; minimum, Rutherford type, alcohol in glass.

was slightly warmer than is usual. December was the coldest month, with a mean temperature slightly below the average for December. The twenty-eight year averages show that the coldest months are normally December and January. January, 1915,

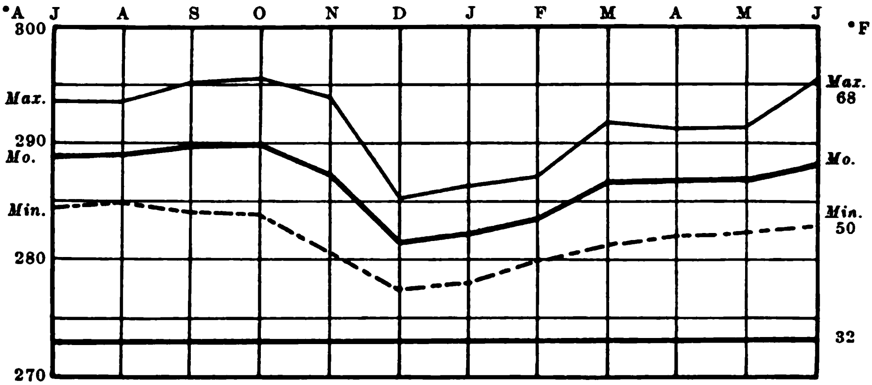

Fig. 2. Annual march of temperature at Berkeley, California, 1914–1915. *Max.*, mean of the daily maxima; *Min.*, mean of the daily minima; *Mo.*, monthly mean temperature, ½ (maximum + minimum).

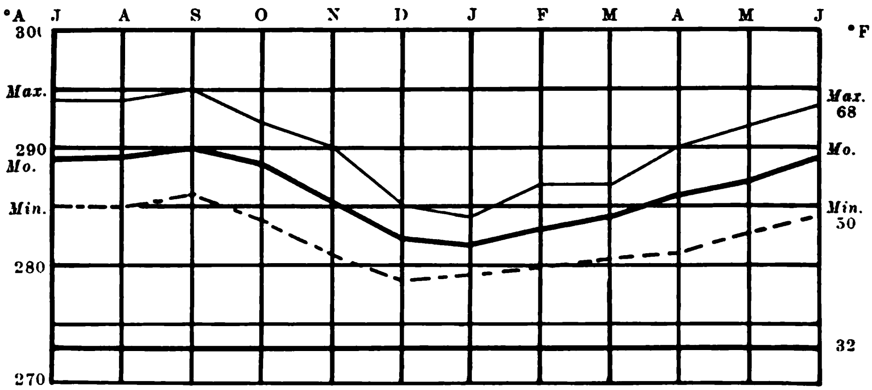

Fig. 3. Average annual march of temperature at Berkeley, California. *Max.*, mean of the daily maxima; *Min.*, mean of the daily minima; *Mo.*, monthly mean temperature, ½ (maximum + minimum).

had a mean temperature not far from the average for the whole period. The greatest departure of mean temperature from the average for the whole period was that of March, which was about three degrees Absolute, five degrees Fahrenheit, warmer than the average.

TEMPERATURE EXTREMES AND RANGES

The statements regarding monthly mean temperatures apply equally to the mean extreme temperatures. The mean daily range was ten degrees Absolute, seventeen degrees Fahrenheit, with a variation of mean daily ranges by months from seven degrees Absolute, thirteen degrees Fahrenheit, for February, to thirteen degrees Absolute, twenty-three degrees Fahrenheit, for November. The amount of the daily range depends to a large extent upon the sunshine and cloudiness; months with considerable cyclonic or velo cloud have small daily ranges. The greatest daily range of the year, twenty-three degrees Absolute, forty-one degrees Fahrenheit, occurred on September 10, which was the day with the highest mean temperature, and also the day with the highest maximum. The smallest daily range was two degrees Absolute, three degrees Fahrenheit, on May 10, during a period of cyclonic rainfall, although the pressure relations at this time are somewhat obscure. The annual mean range, that is, the temperature difference between the warmest and the coldest month, for 1914–1915, was nine degrees Absolute, fifteen degrees Fahrenheit; this is slightly less than the mean daily range. The average of the twenty-eight years is eight degrees Absolute, fifteen degrees Fahrenheit, which is the same as the mean daily range for the twenty-eight years. As has been previously pointed out, this correspondence is due to the location of Berkeley on the "meteorological tropic."

The maximum temperature recorded during the year was 307° A, 94° F, at 15^{hrs}, 3 P.M., on September 10, and the lowest temperature was 274° A, 36° F, at 7^{hrs}, 7 A.M., on December 8. Therefore the annual extreme range was thirty-three degrees Absolute, fifty-eight degrees Fahrenheit. The maximum temperature in a month commonly occurs on the warmest day of the month; in 1914–1915 this was the case in all months except January, March, and April. The occurrence of the minimum temperature of the month on the coldest day is not nearly as usual. In 1914–1915 the minimum for the month occurred on the coldest day in August, November, February, April, and May. Table IV is a summary of the temperature extremes for the year 1914–1915 and for the whole period of the record.

TABLE IV

Extreme Temperatures at Berkeley, California

Maximum temperatures from Negretti and Zambra maximum thermometers; minimum temperatures from Rutherford minimum thermometers; times from thermograph trace.

MAXIMUM

	July, 1914–June, 1915				July, 1887–June, 1915		
Month	**° A**	**° F**	**Date**	**Hour***	**° A**	**° F**	**Date**
July	299	79	14	12 (noon)	309	97	7, 1905
August	300	81	1	13 (1 p.m.)	307	93	22, 1891
September	307	94	10	15 (3 p.m.)	314	106	16, 1914
October	306	91	14	14 (2 p.m.)	308	95	1, 1914
November	301	82	8	14 (2 p.m.)	301	82	16, 1895
December	293	67	22	14 (2 p.m.)	294	70	24, 1901
January	290	62	22	15 (3 p.m.)	298	77	26, 1899
February	290	63	25	15 (3 p.m.)	299	80	18, 1899
March	303	85	22	15 (3 p.m.)	304	87	17, 18, 1914
April	298	76	9	15 (3 p.m.)	303	87	24, 1913
May	302	84	27	10 (a.m.)	307	92	26, 1896
June	303	85	3	16 (4 p.m.)	311	101	6, 1903
Year	307	94	Sept. 10	15 (3 p.m.)	314	106	Sept. 16, 1914

MINIMUM

	July, 1914–June, 1915				July, 1887–June, 1915		
Month	**° A**	**° F**	**Date**	**Hour***	**° A**	**° F**	**Date**
July	283	50	11	4 (a.m.)	288	42	29, 1899
August	283	50	30	4 (a.m.)	281	46	31, 1905
September	282	49	12	5 (a.m.)	281	46	28, 1905
October	280	45	22	7 (a.m.)	277	39	18, 1905
November	278	40	30	3 (a.m.)	274	33	28, 1905
December	274	33	8	7 (a.m.)	272	31	24, 1905
January	275	36	17	7 (a.m.)	269	25	14, 1888
February	276	37	21	2 (a.m.)	271	29	12, 1905
March	278	40	2	6 (a.m.)	274	34	30, 1905
April	279	44	30	6 (a.m.)	275	36	19, 1896
May	278	41	2	2 (a.m.)	277	40	1, 1899
June	281	48	14	4 (a.m.)	279	42	2, 1903
Year	274	33	Dec. 8	7 (a.m.)	269	25	Jan. 14, 1888

* Mean civil time of the 120th Meridian west from Greenwich.

ATMOSPHERIC MOISTURE

Observations

Measurements of atmospheric moisture at Berkeley are still somewhat unsatisfactory because of the inadequate ventilation of the psychrometer. However, the importance of moisture data makes it desirable to include them. Table I shows the mean dew points at the observation hours by the months and for the year. The dew points represent within the accuracy of the observations the moisture content of the air, or, more strictly, the temperature of saturated vapor of the amount of moisture present at the times stated. Fragmentary studies at Berkeley and more complete studies elsewhere[9] indicate that the amount of moisture changes slowly, and, consequently, that the dew points as stated in tables I and II represent the general saturation temperatures for 1914-1915 and for the twenty-three years when observations have been made at 8^{hrs} and 20^{hrs}, 8 A.M. and 8 P.M., of the months and the year.

Dew Points and Relative Humidities

The range of monthly dew points during 1914–1915 was from 277° A, 40° F, to 287° A, 57° F, following the air temperatures very closely. Vapor pressures and relative humidities at the observation hours are also stated. The relative humidity was slightly higher than the average of the twenty-three years of the record, although the differences are not great. Humidities as high as 100 per cent were frequently recorded in fogs, and in a few instances, during "north wind" conditions, humidities of 20 per cent or less were observed. There is a continuous record of humidities from the hygrograph, but it has not been practicable to tabulate the records.

Saturation Deficit

In table V an attempt has been made to show the average of the greatest strain on organisms each day. This strain is, perhaps, best indicated by the maximum saturation deficit, which is

[9] See Day, P. C., "The Relative Humidity of the United States," Monthly Weather Review, Supplement, Washington, 1917.

the saturation deficit[10] at the time of maximum temperature. The values given in the table are to be regarded as approximations, as they were obtained from the mean maximum temperatures and from vapor pressures computed from psychrometer readings at 20^{hrs}, 8 P.M. This is incorrect in theory, as the saturation pressure increases much more rapidly than the temperature, but a study of the actual saturation deficits at selected times showed that no appreciable error was introduced. This is true because the curve of saturation pressures for the portion of the temperature scale involved at Berkeley approaches a straight line. The errors resulting from the use of an admittedly faulty method are surely less than those resulting from the inadequate ventilation of the psychrometer. As these data are of so great importance to agricultural climatology, they have been included, although they have been stated to whole millibars or hundredths of an inch only.

Cloudiness

Cloudiness at Berkeley, especially in summer, is closely related to atmospheric moisture. As is usual at a second-order station, cloudiness records are available only at the observation hours. The station is in possession of a Campbell-Stokes sunshine recorder, but conditions not within the control of the Department of Geography have prevented the installation of the instrument. Automatic records of sunshine will be made as soon as it is possible to install the instrument, which depends upon the designation of a permanent site for the meteorological station in accordance with the permanent building plan. The summer cloud at Berkeley is usually the low stratus or velo[11] cloud, locally in California known as "high fog"; the winter cloud is almost always of cyclonic origin, as is some of the summer cloud.

In 1914–1915 July was the month with the greatest amount of cloud at the observation hours, 0.9 in the morning and 0.7 in the evening; this is about 50 per cent greater than the average

10 The *saturation deficit* may be defined as the difference between the vapor pressure at any time and the saturation pressure at the current temperature. It is a measure of the lack of saturation and hence of the tendency to evaporation.

11 See Carpenter, F. A., The Climate and Weather of San Diego, California, San Diego, 1913, pp. 5–7.

TABLE V

MEAN DAILY MAXIMUM SATURATION DEFICIT AT BERKELEY, CALIFORNIA

(Difference between saturation pressure and actual vapor pressure at time of daily maximum temperature.)

Month	1914–1915		1892–1915	
1914	Mb.	In.	Mb.	In.
July	7	0.28	8	0.30
August	7	.28	7	.26
September	10	.38	8	.30
October	11	.41	7	.28
November	11	.41	5	.20
December	4	.15	4	.14
1915				
January	4	0.16	3	0.11
February	4	.15	4	.16
March	4	.25	3	.11
April	6	.23	6	.22
May	6	.23	7	.25
June	8	.24	8	.31
1914–1915				
Year	7	0.26	6	0.22

NOTE.—These values were estimated from saturation pressures determined from the mean maximum temperatures by the use of the Marvin tables (U. S. Weather Bureau, Psychrometric tables for obtaining the vapor pressure, relative humidity, and temperature of the dew point from readings of the wet and dry bulb thermometers, Washington, 1912) and the average 20^{hrs}, 8 P.M., vapor pressures. A partial study showed that the errors of this method are small and have a tendency to cancel out. It is probable that the errors in the result shown in the table are less than those due to exposure conditions.

for the twenty-three years. There has undoubtedly been a variation in the personal equation of the cloud observations from time to time, but this can hardly be as great as 50 per cent. In July, 1914, the cloudiness was all the result of velo cloud, which was recorded at one or both observations on twenty-two dates. The smallest amount of cloud for any month was 0.2 at each observation hour for November; this is half the average for the twenty-three years. The average cloudiness at the observation hours for 1914–1915 was 0.5, which is about the average amount.

WEATHER

STATE OF THE SKY

The state of the sky is to a considerable extent shown by the cloudiness at the observation hours. However, the times of observation are not well selected to show the conditions in the middle of the day, which may differ from those in the morning

and evening. The general character of each day has been recorded; the summary appears in table I. The average of the records of the character of the day for the twenty-eight years of the record appears in table II. Figure 4 shows the conditions

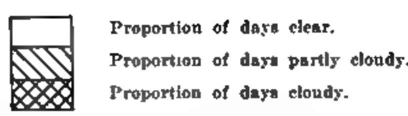

Fig. 4. State of the sky at Berkeley, California, 1914–1915.

of 1914–1915 graphically, and figure 5 shows the twenty-eight year average in the same manner. The character of the day, clear, partly cloudy, or cloudy, has been determined from casual observations through the day and has been recorded regardless of other phenomena, such as precipitation. Fog was treated exactly like cloud.

Of the total of 365 days in 1914–1915, 162 were clear, 92 were partly cloudy, and 111 were cloudy. Clear days are those on which the cloudiness was less than three-tenths through the day, or on which the sky was cloud-covered for less than three-

Proportion of days clear.
Proportion of days partly cloudy.
Proportion of days cloudy.

Fig. 5. Average state of the sky at Berkeley, California, July 1, 1887, to June 30, 1915

tenths of the time. These are the sunny days with starlight nights, anticyclonic weather in winter and non-foggy days in summer; these days have the largest temperature ranges. The months with the greatest number of clear days were October and June, with twenty-two clear days each, and the month with the

smallest number was February, with six. Table II shows that October, November, and June have the greatest average number of clear days, fifteen each, and that August has the smallest number, nine. The average for the year is 156.

As has been noted in the previous reports, the partly cloudy days may be divided into two groups: those on which the sky was from three-tenths to seven-tenths cloud-covered through the day, and those on which the sky was more or less overcast for a part of the day, usually morning and evening. The first group is associated with the margin of a cyclone and is, therefore, a winter rather than a summer phenomenon, although not unknown in the summer. The second type is associated with fog or velo cloud conditions in the morning and evening with clear sky through the day; this type is more common in summer, although it occurs with tule fog[12] in winter, and also sometimes with the approach or departure of a cyclone. Of the ninety-two partly cloudy days recorded in 1914–1915 the greatest number in a single month was eighteen in August, and the smallest was three in November. The average number of partly cloudy days for the twenty-eight years is ninety, the largest monthly average is nine in August, and the smallest average is six in November and February.

Cloudy days occur in winter with cyclones and in summer when the velo cloud persists through the day. Of the 111 cloudy days of 1914–1915 the greatest monthly number was sixteen in January and the least was one in June. The average number of cloudy days for the full period of the record is 119, with the highest monthly average thirteen in August and the lowest seven in June. Under the conditions of observation at Berkeley, the distinction between clear and partly cloudy days is usually well marked, and the records of different observers show practically the same number of clear days; but the distinction between partly cloudy and cloudy days is not so sharp, and different observers often estimate the same day as cloudy or partly cloudy,

[12] This type of fog, so called because it forms over the tule marshes of the lower Sacramento River, is a strongly developed radiation fog. At Berkeley it is usually imported by drifting with the light airs from the north at a rate of about two kilometers (one mile) an hour, arriving at Berkeley about sunrise on quiet anticyclonic days in winter.

the difference being due in part to differences in the personal equation and in part to differences in the exact times when sky conditions are noted.

Fog

At stations near the California coast the adequate treatment of fog is difficult if not impossible without much more frequent observations than are now available. Among the difficulties at Berkeley may be noted the broken character of the topography, with the resulting difference in altitude, which makes any record of fog according to the ruling of the International Meteorological Committee[13] applicable only to the spot where the observation was made. The difficulty is not so great in the case of the "tule" fogs of winter, which are very dense and fill the valleys, including the valley of San Francisco Bay, to the top of the fog layer; this is usually clearly marked at a hundred to a hundred and fifty meters, three to five hundred feet, above sea-level. As has been noted, this type of fog forms over the lower Sacramento marshes and is carried southward from Carquinez Strait by light airs.

The summer fog is a much more complex phenomenon. It is partly formed over the Pacific Ocean, probably by mixture, and is carried to the land by the westerly winds of summer. This type of fog has a tendency to be carried in through the Golden Gate and across San Francisco Bay in detached masses. At times this fog comes in at the surface of the earth and at times it appears as a low stratus or fracto-stratus cloud—the velo cloud of Carpenter.[14] A further difficulty results from the fact that the fog is not always formed over the ocean, but the wind with a high relative humidity blows in from the ocean. Under this condition the slight cooling resulting from the deflection upward by the Berkeley Hills is frequently sufficient to produce fog. All gradations exist, from a dense surface fog enveloping the whole of the Bay Region to small patches of fracto-stratus cloud on the higher portions of the Berkeley Hills.

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13 "Fog is to be recorded only when the observer is enveloped in it." Internationaler Meteorölogischer Kodex, ed. 2, Berlin, 1911.

14 Carpenter, F. A., The Climate and Weather of San Diego, California, San Diego, 1913, pp. 5–7.

In table I are recorded for each month the number of days (i.e., civil dates of the 120th meridian) on which fog occurred on the University campus. This number varied from a maximum of seven in June to a minimum of none in February. The "Extracts from the monthly reports," on pages 459 to 465, show in addition the number of days on which velo cloud occurred. The greatest number of such days in a single month was twenty-two in July and the same number in August; the greatest number recorded in a single month appears to be twenty-five in August, 1895. No velo cloud was recorded from October to February, inclusive. Table II shows the average number of days with fog for the whole period of the record. It should be noted that the original record shows that the difficulty of distinguishing between fog as defined by the International Meteorological Committee and some occurrences which should be regarded as velo cloud has made the record not strictly homogeneous throughout. The summer months, particularly July and August, are those in which fog is most common, although fewer than half the days have fog even in these months. Fog is not common during the winter and spring months.

FROST

Although the frost record for Berkeley is not complete, this phenomenon seems to occur annually at Berkeley; it is probable, however, that frosts properly classed as "killing" do not occur every winter. Since 1912 frost has been recorded whenever a deposit of hoar frost was seen by the observer, and this appears to have been the usual practice before 1912. Frost is limited to the winter months; light or heavy frosts occur more or less frequently between early November and early April. In 1914–1915 frost was recorded on fourteen mornings, of which eleven were in December and three were in January. November and March were too warm for frost, and February was a month of cloud and rain, which prevented nocturnal cooling. Frost characteristically occurs at Berkeley on anticyclonic nights when the terrestrial radiation is strong, usually after considerable transfer of air from the dry continental interior.

Thunderstorms

As thunderstorms are not common on the California coast, no attempt has been made to compile the record of thunderstorm days for the twenty-eight years since the station at Berkeley was established. The record for San Francisco, however, shows that the average for the region is about one a year, although the number has varied from eight in 1906 to none in each of eight years between 1893 and 1912. "The storms are mild in character, the lightning flashes of moderate intensity, and the thunder is usually limited to a few peals. Damage from lightning is practically unknown, although some flagpoles have been shattered and one or two trees struck in the past sixty years."[15]

At Berkeley in 1914–1915 but one thunderstorm was recorded, although lightning was reported once in addition (January 11).[16] The thunderstorm occurred about noon on February 16 and was accompanied by hail. An unusual feature of this thunderstorm was its time of occurrence, the relatively rare thunderstorms of west coast regions almost always occurring at night during periods of cyclonic cloud. February 16, 1915, appears from the barograph trace to be about the middle of a cyclonic period, and showers occurred during the day and the preceding night.

Days With Significant Precipitation

The number of days with measurable precipitation (0.2 millimeter, 0.01 inch, or more) was eighty-seven for the year, which is about 30 per cent more than the twenty-eight year average. The greatest number of rainy days in any one month was nineteen in February, making a new record for this month. This number has been exceeded in only three months since the beginning of the record: twenty-four in December, 1889; twenty-one in January, 1890; and twenty-five in January, 1909. The number of rainy days in each month of the year ending June 30, 1915, is given in table I; the average for the twenty-eight years by months is given in table II.

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[15] McAdie, A. G., The Climate of San Francisco, U. S. Weather Bur. Bull. 44, Washington, 1913, p. 18; see also Alexander, W. H., Distribution of Thunderstorms in the United States, Mo. Weather Review, vol. 43, pp. 322–340, Washington, 1915, especially p. 325 and p. 338.

[16] See Internationaler Meteorologischer Kodex, ed. 2, Berlin, 1911, p. 19: "Only days on which both thunder and lightning are observed are to be counted as days with thunderstorms."

Figure 6 shows graphically the percentage of days with 0.2 millimeter, 0.01 inch, or more, for each month of the year; similar diagrams have appeared in the two preceding reports. A new feature of the diagram in the present report is the addition of the percentage of days with 1.0 millimeter, 0.04 inch, or more, shown by the broken line; it has not been practicable to compute the average number of days with 1.0 millimeter; the record since

Fig. 6. Average probability of days with measurable precipitation (0.2 millimeter, 0.01 inch, or more) at Berkeley, California; and per cent of days with measurable precipitation, 1914–1915 (scale at the left). Also average probability of days without measurable precipitation and per cent of days without measurable precipitation, 1914–1915 (scale at the right).

Shaded area indicates probability of rainy days.
Solid line indicates per cent of days with 0.2 millimeter precipitation, 1914–1915
Broken line indicates per cent of days with 1.0 millimeter precipitation, 1914–1915, where it differs from the per cent of days with 0.2 millimeters.

July, 1912, will be found in the reports since that time. Of course such days form a somewhat smaller percentage of the days than those with 0.2 millimeter, but the closeness of the two lines is striking. It is possible to read figure 6 from the point of view of days without measurable precipitation by means of the scale at the right. The area above the line represents the

proportion of the days without measurable precipitation; this is more striking than the number of days with rain. The shaded area shows the average number of days with precipitation of 0.2 millimeter or more. Figure 10 on page 489 shows the actual occurrence of rainy days during 1914–1915.

Table VI and figure 7 are attempts to show the duration of periods without measurable precipitation and of continuous pe-

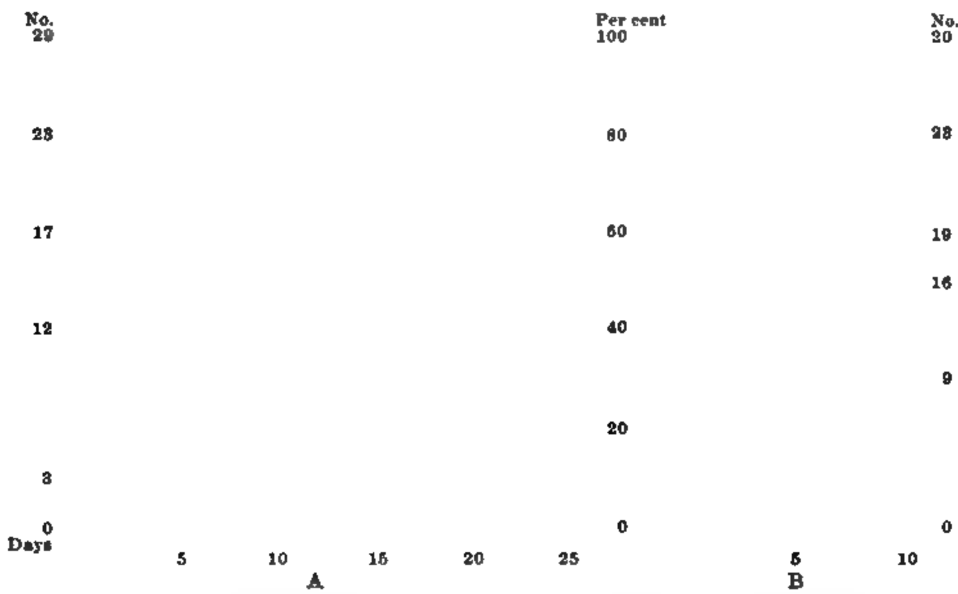

Fig. 7. A, consecutive days without precipitation; B, consecutive days with precipitation; Berkeley, California, September 7, 1914, to May 24, 1915.

riods during which the daily rainfall was 0.2 millimeter or more. All records of rainy days are referred to the rainfall day of the station, which is the twenty-four hours ending at 20^{hrs}, 8 P.M., mean civil time of the 120th meridian. The date is the civil date on which the last twenty hours of the rainfall day falls; that is, the rainfall day ends four hours before the civil day. Diagram A of figure 7 shows by the shaded area the percentage of occurrence of rainless periods of different duration between the first rain in autumn, September 7, and the last rain in spring, May 25. Of a total of twenty-nine such periods, three were of one day's duration, nine were of two days' duration, and so forth. The

TABLE VI

RAIN PERIODS AT BERKELEY, CALIFORNIA, 1914–1915

Date of beginning and ending	Number of consecutive days with rain	Number of consecutive days without rain
June 25–September 6	....	74
September 7–September 7	1	....
September 8–October 1	....	24
October 2–October 2	1	....
October 3–October 7	....	5
October 8–October 9	2	....
October 10–October 16	....	7
October 16–October 17	2	....
October 18–October 31	....	13
November 1–November 1	1	....
November 2–November 26	....	25
November 27–November 29	3	....
November 30–November 30	....	1
December 1–December 6	6	....
December 7–December 8	....	2
December 9–December 11	3	....
December 12–December 15	....	4
December 16–December 20	5	....
December 21–December 25	....	5
December 26–December 29	4	....
December 30–January 2	....	4
January 3–January 6	4	....
January 7–January 7	....	1
January 8–January 8	1	....
January 9–January 10	....	2
January 11–January 14	4	....
January 15–January 20	....	6
January 21–January 21	1	....
January 22–January 24	....	3
January 25–February 4	11	....
February 5–February 6	....	2
February 7–February 11	5	....
February 12–February 15	....	4
February 16–February 20	5	....
February 21–February 21	....	1
February 22–February 24	3	....
February 25–February 26	....	2
February 27–February 28	2	....
March 1–March 8	....	8
March 9–March 9	1	....
March 10–March 11	....	2
March 12–March 13	2	....
March 14–March 25	....	12
March 26–March 31	6	....

TABLE VI—(*Continued*)

Date of beginning and ending	Number of consecutive days with rain	Number of consecutive days without rain
April 1–April 6	....	6
April 7–April 7	1	....
April 8–April 11	....	4
April 12–April 12	1	....
April 13–April 24	....	12
April 25–April 26	2	....
April 27–April 28	....	2
April 29–April 29	1	....
April 30–May 1	....	2
May 2–May 5	4	....
May 6–May 7	....	2
May 8–May 13	6	....
May 14–May 15	....	2
May 16–May 17	2	....
May 18–May 22	....	5
May 23–May 24	2	....
May 25–July 3	....	40

SUMMARY

Periods of 1 day	9	3
Periods of 2 days	7	9
Periods of 3 days	3	1
Periods of 4 days	4	4
Periods of 5 days	3	3
Periods of 6 days	3	2
Periods of 7 days	0	1
Periods of 8 days	0	1
Periods of 9 days	0	0
Periods of 10 days or more	1	7
Total*	30	31

* June 25, 1914, to July 4, 1915, inclusive.

line is a summation of the periods shown by the shaded areas; for example, twelve periods or 40 per cent of the total lasted for two days or less. There was no period without rain of more than twenty-five days' duration, except the long dry summer at the beginning and end of the meteorological year; this is not shown by the diagram. The record has included only the fact of precipitation of 0.2 millimeter, 0.01 inch, or more on the rainfall day; if rain was falling long enough before and after 20^{hrs}, 8 P.M., for a measurable amount to be collected, both rainfall days were counted as days with precipitation.

Figure 7B is similar to figure 7A, except that it shows periods of consecutive rainfall days on which measurable precipitation occurred. There were during the year thirty such periods. Of these nine, or 30 per cent, occurred within one rainfall day; seven, or 23 per cent, occurred on two rainfall days, and so forth. The longest period with daily rain was eleven days. The line is the summation of the periods shown by the shaded areas.

PRECIPITATION

Monthly Amounts

The total precipitation for the year 1914–1915 was 786.1 millimeters, 30.95 inches, which is 107.4 millimeters, 4.20 inches,

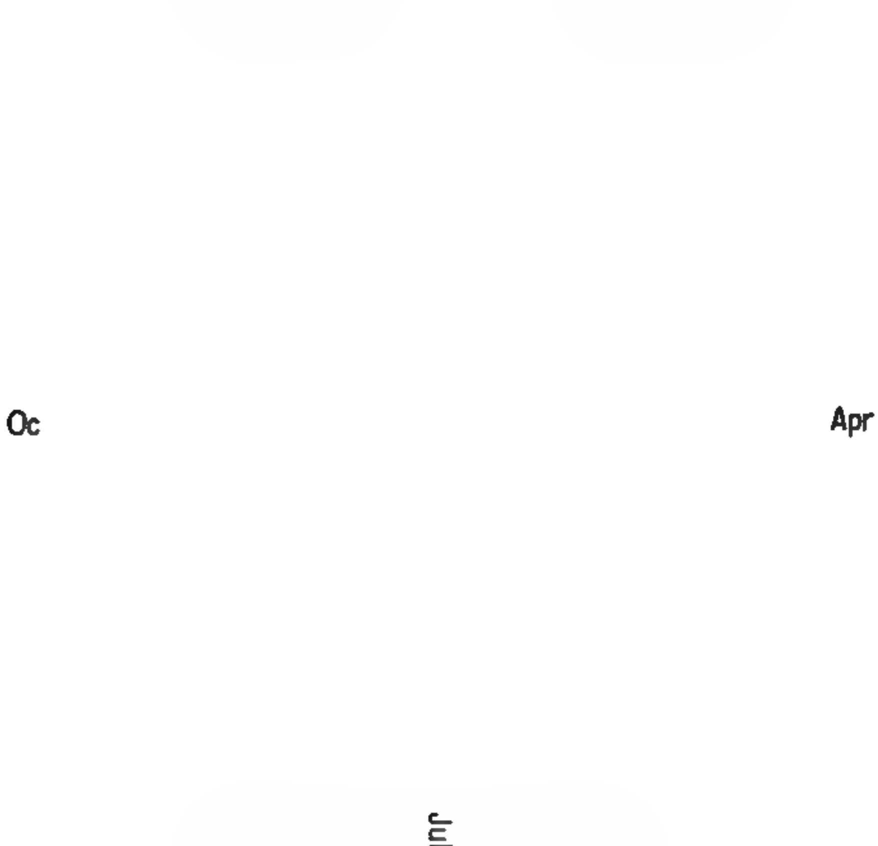

Fig. 8. Monthly precipitation at Berkeley, California, 1914–1915, and (shaded area) average monthly precipitation, 1887–1915.

that is, 16 per cent, more than the average annual amount based on the twenty-eight years of the Berkeley record. The precipitation for each month is shown by table I, and the monthly averages appear in table II. Figure 8 shows the data graphically. No rain fell in August or June, and only a trace in July. The rainiest month was February, with 207.8 millimeters, 8.18 inches; this is nearly twice the February average. The May rainfall, 133.6 millimeters, or 5.26 inches, is a new record for May; it is 46.5 millimeters, 1.83 inches, more than the amount

Fig. 9. Accumulated precipitation at Berkeley, California, 1914–1915. Shaded area indicates average accumulated precipitation at Berkeley, 1887–1915.

for May, 1905, the May of heaviest precipitation previous to 1915.

Table VII and figure 9 show the accumulated amounts of precipitation from July 1 both for 1914–1915 and for the whole period of the record. The shaded area of the figure is the average accumulated precipitation computed at the end of each month. The line shows the accumulated amounts for 1914–1915; the amounts are computed at the end of each period of rain. Table VII shows the accumulated excess or deficiency in precipitation at the end of each month of 1914–1915 as compared with the

average of the twenty-eight years. The accumulated amounts for the year were below the average until January, but after that month there was an excess. At the end of May the excess was 112.7 millimeters (4.44 inches); but on account of the dry June, the excess at the end of the meteorological year was only 107.4 millimeters (4.20 inches).

DAILY AMOUNTS

The rainfall for 1914–1915 is shown for each rainfall day, ending at 10 p.m., 120th meridian time, by table VIII for each day on which precipitation occurred. The daily precipitation

TABLE VII

MONTHLY AND SEASONAL PRECIPITATION AT BERKELEY, CALIFORNIA, JULY 1, 1914–JUNE 30, 1915, WITH AVERAGES FOR TWENTY-EIGHT YEARS AND DEPARTURES FROM THE AVERAGES

Month	Monthly		Seasonal to end of month		Average seasonal		Departure, 1914–1915	
1914	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
July	0.0	0.0	0.0	0.0	0.5	0.02	— 0.5	—0.02
August			0.0	0.0	1.5	0.06	— 1.5	—0.06
September	0.5	0.02	0.5	0.02	16.2	0.64	— 15.7	—0.62
October	21.3	0.84	21.8	0.86	52.6	2.07	— 30.8	—1.21
November	10.9	0.43	32.7	1.29	120.8	4.75	— 88.1	—3.46
December	167.1	6.58	199.8	7.87	229.7	9.04	— 29.9	—1.17
1915								
January	176.8	6.96	376.6	14.83	382.6	15.05	— 6.0	—0.23
February	207.6	8.18	584.2	23.01	488.5	19.22	+ 95.7	+3.79
March	46.7	1.83	630.9	24.84	604.8	23.81	+ 26.1	+1.03
April	21.6	0.85	652.5	25.69	641.2	25.24	+ 11.3	+0.45
May	133.6	5.26	786.1	30.95	673.4	26.51	+112.7	+4.44
June			786.1	30.95	678.7	26.72	+107.4	+4.23
1914–15								
Season	786.1	30.95	786.1	30.95	678.7	26.72	+107.4	+4.20

NOTE.—Absence of precipitation, ——; trace, 0.0.

is also shown graphically by figure 10: in this figure the length of the vertical line for each day with rain is proportionate to the amount of the fall; the lines are located at the appropriate position in each month; for days on which no precipitation was recorded the space is left blank. There were ninety-five rainfall days on which precipitation was recorded; on eight of these days

mm. 40 | inches 1.57
30 | 1.18
20 | 0.79
10 | 0.39
0 | 0

Fig. 10. Precipitation at Berkeley, California, 1914–1915, by rainfall days ending at 20^{hrs} mean civil time of the 120th meridian west from Greenwich, 8 P.M. Pacific Standard time, 4^{hrs} Greenwich mean civil time.

the amount was only a trace, leaving a total of eighty-seven rainfall days with measurable precipitation, 0.2 millimeter, 0.01 inch, or more. There were seventy-five days with significant precipitation, 1.0 millimeter, 0.04 inch, or more; thirty-four with 10.0 millimeters, 0.4 inch, or more; and five with 25.0 millimeters, 1.0 inch, or more. The number of rainy days in each month is shown by table I and by figure 6.

The greatest amount of precipitation on any rainfall day in 1914–1915 was 35.5 millimeters, 1.40 inches, on December 16. The greatest amount in any twenty-four hour period ending at 8^{hrs}, 8 A.M., or 20^{hrs}, 8 P.M., 120th meridian time, 16^{hrs} or 4^{hrs}, Greenwich mean civil time, was 43.7 millimeters, 1.72 inches, for the twenty-four hours ending at 8^{hrs}, 8 A.M., December 17. Figure 10 shows the grouping of rainy days into periods because of the cyclonic control of rainfall at Berkeley. It also shows clearly the characteristic concentration of the rain in the winter months. The unusually rainy character of May stands out very clearly in this figure, especially if it is compared with figure 9 in the report for 1913–1914,[17] which shows a more normal May. The figure is also of interest because it emphasizes the number of days without rain, not only in the dry summer but also in winter, the so-called rainy season.

TABLE VIII

PRECIPITATION AT BERKELEY, CALIFORNIA, 1914–1915, BY RAINFALL DAYS

The rainfall day is the 24 hours ending at 20^{hrs}, 8 P.M., mean civil time of the 120th Meridian west from Greenwich (4^{hrs} Greenwich mean civil time).

Cyclone number	Date 1914		Amount Mm.	Amount In.	Cyclone number	Date 1915		Amount Mm.	Amount In.
1	July	11	.0.0	.0.0	7		29	2.0	0.08
XX	Sept.	7	0.5	0.02		Dec.	1	12.2	0.47
2	Oct.	2	0.2	0.01			2	18.0	0.71
3		8	0.3	0.01			3	4.3	0.17
		9	.0.0	.0.0			4	8.4	0.33
4		17	15.5	0.61			5	4.3	0.17
		18	5.3	0.21			6	6.3	0.25
5	Nov.	1	5.6	0.22	8		9	15.0	0.59
6		27	1.3	0.05			10	17.5	0.69
		28	2.0	0.08			11	6.8	0.27

[17] Univ. Calif. Publ. Geog., vol. 1, no. 9, pp. 373–439, Berkeley, April 10. 1916, facing p. 436.

Cyclone number	Date 1915	Amount Mm.	Amount In.	Cyclone number	Date 1915	Amount Mm.	Amount In.
9	16	35.5	1.40	22	18	0.8	0.03
	17	27.7	1.09		19	0.5	0.02
10	18	2.8	0.11		20	13.0	0.51
	19	3.8	0.15				
	20	.0.0	.0.0	23	22	26.9	1.06
				24	23	5.6	0.22
11	26	4.5	0.18		24	9.4	0.37
	27	.0.0	.0.0	25	27	10.2	0.40
	28	.0.0	.0.0		28	1.0	0.04
	29	.0.0	.0.0				
					Mar. 4	.0.0	.0.0
12	Jan. 3	8.4	0.33	26	9	1.0	0.04
				27	12	4.3	0.17
13	4	3.6	0.14		13	1.0	0.04
	5	0 5	0.02	28	26	0.5	0.02
	6	19.3	0.76				
14	8	23.9	0.94	29	27	7.6	0.30
15	11	10.4	0.41		28	12.0	0.47
					29	4.9	0.19
16	12	3.8	0.15	30	30	12.4	0.49
	13	12.2	0.48		31	2.8	0.11
	14	10.8	0.42				
17	21	3.1	0.12	31	Apr. 7	3.6	0.14
	25	9.9	0.39	32	12	3.0	0.12
					21	.0.0	.0.0
18	26	3.6	0.14	33	25	5.1	0.20
	27	14.7	0.58	34	26	8.4	0.33
	28	8.4	0.33				
	29	14.7	0.58		29	1.5	0.06
	30	14.7	0.58	35	May 2	2.4	0.09
				36	3	11.5	0.45
19	31	15.0	0.59		4	16.0	0.63
	Feb. 1	4 3	0.17		5	7.9	0.31
	2	24 4	0.96				
	3	1.3	0.05	37	8	1.0	0.04
	4	7.4	0.29		9	19.0	0.75
				38	10	22.4	0.88
20	7	26.9	1.06		11	27.9	1.10
	8	18.8	0.74		12	11.4	0.45
	9	8.1	0.32				
	10	17.5	0.69		13	0.7	0.03
	11	0.5	0.02	39	16	0.5	0.02
					17	11.7	0.46
21	16	20.8	0.82		23	0.5	0.02
	17	10.4	0.41	40	24	0.7	0.03

NOTE.—.0.0 indicates a trace of precipitation, less than 0.2 millimeter, 0.01 inch.

Table IX is a summary of the daily amounts. It shows the average precipitation for days with measurable and for days with significant precipitation (i.e., days with precipitation $\geq$0.2 mm. and days with precipitation $\geq$1.0 mm., respectively) for each month and for the year. The probable occurrence of rain must be determined in two steps: the first is the probability of a rainy day, and the second the probable amount of rain if the rainy day occurs. Table IX is a first attempt to make practicable the

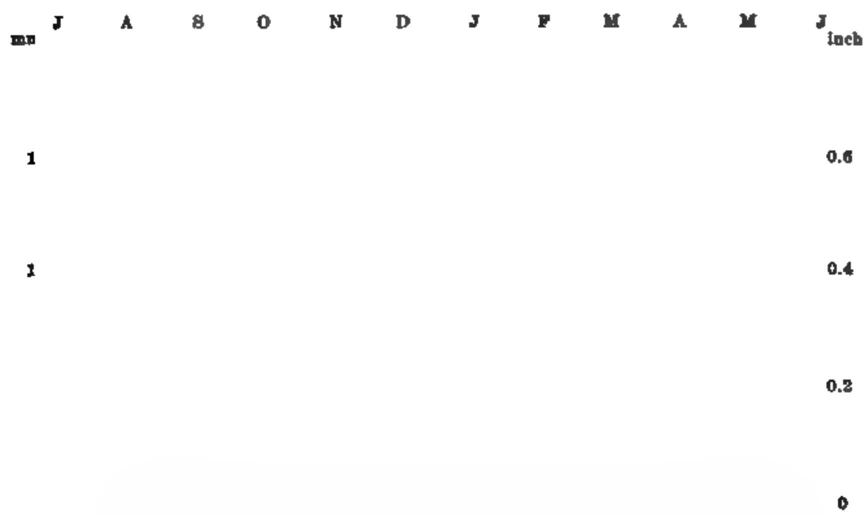

Fig. 11. Average daily precipitation at Berkeley, California, 1914–1915. Light line, average for every day in the month; heavy line, average for days with precipitation 0.2 mm., 0.01 in.; dotted line, average for days with precipitation 1.0 mm., 0.04 in.

answers to such questions. However, too much reliance should not be placed on it, as it represents the conditions of a single year; the work should be carried out for other years, and also for the conditions in the long run.

The same information is shown graphically by figure 11. This figure shows the relative raininess of the month by the thin line; this is obtained by dividing the total precipitation for the month by the whole number of days in the month; it is a method of compensating for the varying length of the months. The average amount of precipitation for each rainfall day on which a measurable amount fell is shown by the heavy line; this is obtained

by dividing the total precipitation for the month by the number of days with precipitation equaling or exceeding 0.2 millimeter. The broken line shows the average amount for each rainfall day on which a significant amount fell; this is obtained by dividing the total amount for the month by the number of days with precipitation equaling or exceeding 1.0 millimeter.

TABLE IX

SUMMARY OF PRECIPITATION BY RAINFALL DAYS, BERKELEY, CALIFORNIA, 1914–1915

The rainfall day is the 24 hours ending at 20hrs, 8 P.M., mean civil time of the 120th Meridian west from Greenwich (4hrs Greenwich mean civil time).

		Days with precipitation			
		$\geqq$0.2 mm.		$\geqq$1.0 mm.	
Month 1914	Total precipitation	No.	Average precipitation Mm.	No.	Average precipitation Mm.
July	.0.0	0	......	0	......
August	.	0	......	0	......
September	0.5	1	0.5	0	......
October	21.3	4	5.3	2	10.4
November	10.9	4	2.7	4	2.7
December	167.1	14	11.9	14	11.9
1915					
January	176.7	17	10.4	16	11.0
February	207.8	19	10.9	16	12.9
March	46.5	9	5.2	8	5.8
April	21.6	5	4.3	5	4.3
May	136.6	14	9.6	10	13.1
June	.	0	......	0	......
Year	786.1	87	9.0	75	10.4

February was the month with the highest average for all days: 7.4 millimeters, 0.29 inch. December had the greatest average for rainfall days with measurable precipitation: 11.9 millimeters, 0.47 inch. May had the greatest average for rainfall days with significant precipitation, 13.1 millimeters, 0.52 inch, although the average amount for February was nearly as great, 12.9 millimeters, 0.51 inch.

As has been previously noted, the curves for number of rainy days, for average precipitation per day of the month, and for total monthly precipitation all follow very closely the annual

march of rainfall. At Berkeley a rainy month is usually a month with a large number of rainy days, and a month with a small number of rainy days is usually dry. The relation will not hold absolutely in all cases, but it is a safe generalization.

Cyclonic Rainfalls

Because of the great importance of the cyclonic rainfall relations, the attempt to report rain by cyclones has been continued; the results appear in table X. It was not practicable for the writer to undertake the study of the weather maps for this report, and hence the map notes are not as complete as in former years. The separation into cyclones was made mainly as a result of the study of the barograph trace at times when precipitation was recorded. As was the case in the previous reports, no attempt is made to record cyclones which did not result in precipitation at Berkeley, no matter what pressure conditions, cyclonic cloud, or other properly cyclonic phenomena occurred at other times; the attempt was to group precipitation by the appropriate cyclones rather than to make a complete study of the cyclonic weather conditions of the year, although it is realized that such a study would be of great value. Forty rainy cyclones were recognized, with a total of 785.6 millimeters, 30.93 inches, of rain. This includes all the rain of the year, except a small amount from a fog shower on September 7, which has been listed in table X without assignment to a cyclone. The average precipitation per cyclone with rain was 19.6 millimeters, 0.77 inch. This is somewhat more than the average for 1913–1914; the difference seems to be real, although in such a matter the success with which cyclones have been separated is an important factor.

The cyclones with the greatest precipitation were numbers 9 and 18, each of which had 66.0 millimeters, 2.60 inches, of rain; the duration of number 9 was four days, and that of number 18 was five days. At least two true cyclones resulted in only a trace of rain at Berkeley; these have been included in table X as number 1 and number 28. The cyclone of longest duration seems to be number 17, which might be considered an attempt to form a true cyclone or a partly developed cyclonic condition rather than a complete cyclone. It has not been practicable to show

TABLE X

No.	Date	Mm.	In.	Barograph trace		Depression Mb.	Depression In.	Weather map notes
1	July 11	.0.0	.0.0	Faint depression		1.7	0.05	No well developed cyclone shown
XX	Sept. 7	0.5	.0.02	—— fog shower		None	None	No cyclone
2	Oct. 1–4	0.2	0.01	Moderate depression		3.4	0.10	Shallow low in British Columbia on 1st, remained there and deepened on 2nd; moved to Colorado on 3rd
3	Oct. 7–9	0.3	0.01	Moderate depression		4.4	0.13	Weak low appeared over Alberta on 8th; another off Oregon coast on 9th
4	Oct. 16–18	20.8	0.82	Sharp depression		6.4	0.19	Low off Puget Sound on 16th; in Alberta on 17th; moving eastward
5	Oct. 31–Nov. 1	5.6	0.22	Faint depression		2.4	0.07	Low in Manitoba on 31st
6	Nov. 26–29	5.3	0.21	Marked depression	Fall	4.1	0.12	Low off North Pacific coast, moving westward
					Rise	7.8	0.23	
7	Nov. 29–Dec. 6	53.4	2.10	Sharp fall to Dec. 1, waves on Dec. 2, unsettled to Dec. 6	Fall	15.2	0.45	More or less stationary low off Washington coast
8	Dec. 8–12	39.3	1.55	Marked depression with waves on Dec. 9		8.5	0.25	Low off Washington on 8th; off Oregon on 9th and 10th; moving to Utah on 11th; in Arizona on 12th
9	Dec. 15–18	66.0	2.60	Sharp fall with waves		15.9	0.47	Low off northern California on 17th
10	Dec. 18–21	3.8	0.15	Moderate fall and irregular to Dec. 19, sharp rise Dec. 20 and 21	Fall	4.4	0.13	Low off Oregon on 19th and in Arizona
					Rise	12.9	0.38	
11	Dec. 25–29	4.6	0.18	Moderate depression to Dec. 28, unsettled to Dec. 29		7.4	0.22	Low off Washington on 26th; disappeared on 28th and 29th
12	Jan. 2–4	11.9	0.47	Moderate depression with waves on Jan. 2 and 3		6.4	0.19	Low in Alberta on 2nd; in Saskatchewan on 4th
13	Jan. 4–7	19.8	0.78	Marked depression		9.1	0.27	Low off Washington on 5th; remained until 8th

TABLE X—(*Continued*)

No.	Date	Mm.	In.	Barograph trace		Depression Mb.	Depression In.	Weather map notes
14	Jan. 7–9	23.9	0.94	Sharp depression with waves on Jan. 8	Fall Rise	7.4 12.2	0.22 0.36	Low off Washington on 8th; on 9th in Alberta
15	Jan. 10–12	11.9	0.47	Sharp depression	Fall Rise	13.5 6.1	0.40 0.18	Low in western British Columbia on 11th; in Alberta on 12th
16	Jan. 12–14	25.2	0.99	Unsettled with weak depression	Fall Rise	3.7 6.4	0.11 0.19	Low in western British Columbia on 13th; off Washington on 14th
17	Jan. 19–25	3.1	0.12	Unsettled with poorly marked depression and waves		?	?	Low coming on 19th and 20th off Oregon coast; never arrived; low in Alberta 23rd to 25th
18	Jan. 26–30	66.0	2.60	Strong depression		27.8	0.82	Low off northern California and Oregon 26th to 29th; off Oregon on 30th
19	Jan. 31–Feb. 4	52.4	2.06	Very strong depression		36.2	1.07	Deep low off British Columbia on 1st; off Oregon on 2nd; in Montana on 3rd
20	Feb. 5–12	71.7	2.83	Irregular with considerable depression		25.4	0.75	Weak low off Washington on 5th; remained till 10th; on 11th moved south into Utah, on 12th into Colorado
21	Feb. 14–18	32.0	1.26	Moderate depression		10.5	0.31	On 14th low off Oregon coast; on 16th in Oregon, moving eastward
22	Feb. 18–21	13.5	0.53	Weak depression; part of the foregoing?	Fall Rise	6.8 12.2	0.20 0.36	On 20th low off Washington
23	Feb. 21–22	27.0	1.06	Very weak depression		2.4	0.07	Shallow low off Washington
24	Feb. 22–26	15.0	0.59	Marked depression	Fall Rise	11.5 9.5	0.34 0.28	Low remained off northwest Washington 24th to 27th
25	Feb. 27–Mar. 3	11.2	0.44	Moderate depression		13.2	0.39	Low in southern Nevada on March 1st and 2nd, in Texas on 3rd
26	Mar. 6–10	1.0	0.04	Faint depression		6.8?	0.20?	No lows 6th to 8th; shallow low in northern Washington and British Columbia on 9th and 10th

TABLE X—(*Concluded*)

No.	Date	Mm.	In.	Barograph trace		Depression Mb.	Depression In.	Weather map notes
27	Mar. 11–13	5.3	0.21	Faint depression		6.1	0.18	Shallow low in British Columbia on 12th and 13th
28	Mar. 22–26	.0.0	.0.0	Moderate depression with waves March 25–26	Fall Rise	11.8 3.4	0.35 0.10	Shallow low off southern Oregon on 26th
29	Mar. 26–29	25.0	0.98	Moderate depression with continual waves		9.5	0.28	Low off Oregon on 27th; in Idaho on 29th
30	Mar. 30–31	15.2	0.60	Flattening of diurnal		?	?	Low in southwestern British Columbia on 30th and 31st
31	Apr. 6–7	3.6	0.14	Very slight irregularity		......	......	Low in southwestern British Columbia on April 7th
32	Apr. 12	3.0	0.12	Slight flattening		......	......	Low in British Columbia on 12th, in Alberta on 13th
33	Apr. 25–26	13.5	0.53	Faint depression		3.0	0.09	Low in Alberta on 26th
34	Apr. 29	1.5	0.06	Moderate depression		4.7	0.14	Low in northern Idaho
35	Apr. 30–May 2	2.4	0.09	Moderate depression	Fall Rise	6.1 10.8	0.18 0.32	On 30th lows in Montana and Nevada; moved eastward by May 2
36	May 2–6	35.4	1.39	Weak depression		4.7	0.14	No cyclonic relations appear from the maps
37	May 7–9	20.0	0.79	Flattening of diurnal		......	......	Low in Alberta on 8th and 9th
38	May 10–14	62.4	2.46	Moderate depression		7.1	0.21	Low off Washington on 11th and 12th; moved into Nevada on 13th, into Wyoming on 14th
39	May 15–18	12.2	0.48	Marked depression		12.2	0.36	Low in British Columbia on 15th; moved into Colorado by 17th, into New Mexico on 18th
40	May 22–25	1.2	0.05	Weak depression		5.8	0.17	Low in British Columbia on 24th and 25th

* The writer is indebted to Dr. John P. Buwalda for the weather map notes.

typical cyclones in the present report; reference may be made to plates 47 to 55 in the report for 1913–1914, which show the more typical cyclones of the year. The types of cyclones in 1914–1915 were similar to those in the preceding year, so that these plates may be considered as typical of 1914–1915 as of 1913–1914.

WIND DIRECTIONS

At the Observation Hours

Wind direction was observed regularly at 8^{hrs} and 20^{hrs}, 8 A.M. and 8 P.M., 120th meridian time. As it has not yet been possible to install a proper wind vane, the observations are subject to considerable error. A summary of the observations is given in table I. As is usually the case at Berkeley, the greater part of the winds at the observation hours were from southerly and westerly directions; in winter southeast winds are relatively more frequent than in summer, although the winds most often recorded at the observation hours in July were south and southeast. However, the prevailing winds by days for July show southwest and west winds on all days. The observation hours are times at which the wind direction on the campus is most apt to be influenced by feeble drafts from Strawberry Cañon.

The wind directions at the observation hours are the result of one or more of the following tendencies: (1) the prevailing surface drift of the air from a southwesterly or westerly direction; (2) a flow of air from the hills due to local cooling (this is especially important at the time of the evening observation, 20^{hrs}, 8 P.M., 120th meridian time); (3) cyclonic winds, generally from the south or southeast, which are the result of a cyclone center north of Berkeley; and (4) anticyclonic winds resulting from the development of comparatively high pressures more or less connected with the continental hyperbar, these winds being generally from the north or northeast.

All directions except those of the three octants between southeast and west are of comparatively minor importance, although north and northeast winds have a very marked influence on the character of the days on which they occur; these days are hot and dry on account of the dynamic warming of the rapidly

moving and descending air. Their number is, however, very small. Calm was recorded at ninety-four observation hours, which appears to be somewhat less than the average; but, because of the generally low wind velocities, the records made by different observers cannot be regarded as at all homogeneous.

Daily Prevailing Winds

Perhaps a better statement of the wind directions than is possible from the records at the observation hours is the record of the number of days with prevailing wind from each direction. This has been compiled from casual observations during the day, and appears in table I. Although the record of daily prevailing

Fig. 12. Number of days with prevailing wind from each direction, Berkeley, California, 1914–1915. (Circles indicate number of days.)

wind directions for the whole period of the record is available, it has not been practicable to compile the data for the period. Figure 12 is the wind-rose for the year. Its most striking characteristic is the marked preponderance of winds from the southwest quadrant.

The seasonal and monthly distribution of winds from the different directions is shown by table I, and also in part by figures 13 and 14. These two figures and table XI are the result

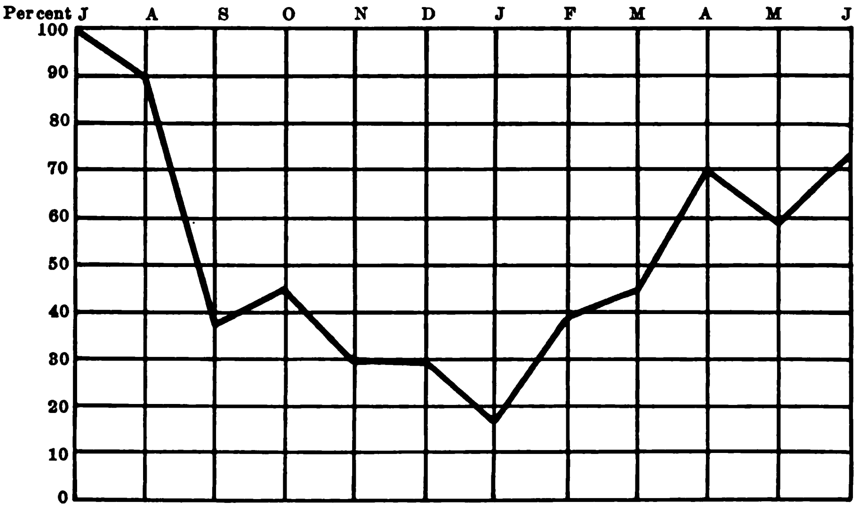

Fig. 13. Percentage of days with the prevailing wind direction southwest or west, Berkeley, California, 1914–1915.

of an attempt to distinguish summer and winter conditions by the daily prevailing winds. Table XI shows the number and percentages by months of the two groups of winds which are of the greatest frequency at Berkeley: the southwest and west, and the southeast and south. Figure 13 shows by months the percentages of days with prevailing winds from the southwest and west. The number varies from all the days, 100 per cent, in July, to five days, 16 per cent, in January. Southwest and west winds are those associated with summer conditions, and hence figure 13 and the same information of table XI may be said to

TABLE XI

SEASONAL CONDITIONS AT BERKELEY, CALIFORNIA, 1914–1915, AS SHOWN BY DAILY PREVAILING WIND DIRECTIONS

Month	Summer directions, SW and W		Winter directions, SE and E	
1914	Number	Per cent	Number	Per cent
July	31	100	0	0
August	28	90	0	0
September	11	37	3	10
October	14	45	3	10
November	9	30	7	23
December	9	29	12	39
1915				
January	5	16	8	26
February	11	39	10	36
March	14	45	5	16
April	21	70	1	3
May	18	58	5	16
June	22	73	1	3
1914–1915				
Year	193	53	55	15

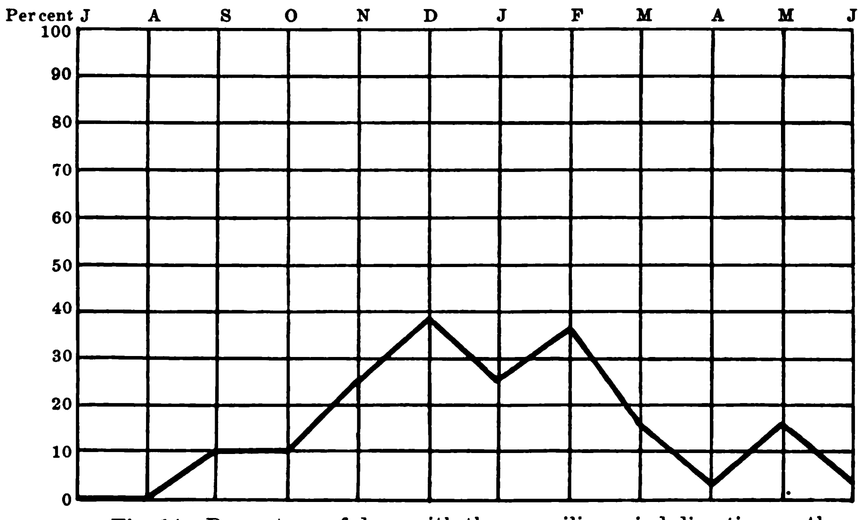

Fig. 14. Percentage of days with the prevailing wind direction south-east or south, Berkeley, California, 1914–1915.

show how far a month has summer characteristics. Figure 14 shows in the same manner the percentage of days with prevailing winds from the southeast and south, the characteristic cyclonic wind directions at Berkeley. This diagram shows the winter characteristics of each month as indicated by the wind directions. As is to be expected, the months with high percentages of summer prevailing winds are those with low percentages of winter prevailing winds. The figures show the seasonal change in the same way as the amounts of precipitation (fig. 8) and the number of rainy days (fig. 6).

SUMMARY

The mean sea-level equivalent of the air pressure at Berkeley for the year ending June 30, 1915, was 1016 millibars, 30.01 inches of mercury, about the average pressure for the twenty-eight years of record. The departures of the monthly means were small and irregular. The highest pressure, 1031 millibars, 30.44 inches, occurred on February 4, and the lowest, 991 millibars, 29.26 inches, on January 29. Neither is a new record for Berkeley, although the minimum for the year was a notably low pressure.

The mean temperature for the year was 287° A, 57° F, which is practically the average for Berkeley; the mean annual range was 9° A, 15° F, and the annual extreme range, 33° A, 58° F. The highest temperature was 307° A, 94° F, on September 10; the lowest was 274° A, 36° F, on December 8. The mean monthly range was 20° A, 36° F; the mean daily range was 10° A, 17° F, varying from 25° A, 45° F, in September, to 14° A, 26° F, in January and February. The greatest daily range was 23° A, 41° F, on September 10, and the smallest was 2° A, 3° F, on May 10. September and October were the warmest months, the mean temperature for October being somewhat higher than the average for that month. December was the coldest month. Frosts occurred mostly in December, when frost was reported on 11 mornings; the other 3 frosts reported were all in January.

The pressure of the water vapor of the atmosphere was generally less than 15 millibars, 0.420 inch. Relative humidities

were slightly higher than the average, being 89 per cent at both morning and evening observation hours. The mean of the saturation deficits for each day at the time of greatest strain on organisms was 7 millibars, 0.26 inch, which is slightly more than the average of the twenty-three years of comparable observations of atmospheric moisture. The average saturation deficit at time of daily maximum temperature was greatest in October and November, 11 millibars, 0.41 inch, and least in January, February, and March, 4 millibars, 0.15 inch. The average cloudiness at the observation hours was 0.5; the greatest monthly average was 0.9 for the morning and 0.7 for the evening hour in July, which is about 50 per cent more than the average; November was the least cloudy month, 0.2 at each observation hour.

The weather by days was as follows: 44 per cent clear, 25 per cent partly cloudy, and 31 per cent cloudy. August had the greatest number of cloudy days (18), and November the smallest (3). June and October each had 22 clear days, and February had 6. Fog as defined by the International Meteorological Committee occurred on 28 days, with a maximum of 7 in June and a minimum of none in February. Velo cloud, or "high fog," occurred on about 50 other days, which is a rather large number. But one thunderstorm occurred during the year, about noon on February 16; a daytime thunderstorm is a very unusual occurrence on the California coast.

The total number of days with measurable precipitation was 87, which is about 30 per cent more than the average. The greatest number in any month was 19, in February. December, January, February, and May had more than the average number of rainy days, the number for May being nearly three times the average. There were 29 periods without rain between the first rain in autumn and the last in spring; of these 40 per cent lasted two days or less, 60 per cent four days or less, 80 per cent six days or less; the longest dry period, except the dry summer, was 25 days. Of the 30 periods of consecutive rainy days 30 per cent lasted one day, 50 per cent two days or less, and 80 per cent four days or less; the longest such period was 11 days.

The total precipitation for the year was 786 millimeters, 30.95 inches, which is 16 per cent more than the average. September,

October, November, March, April, and June had less than the average amount; December, January, February, and May had more than the average. The precipitation of May was the heaviest recorded for that month; it was 134 millimeters, 5.26 inches, which is 418 per cent of the May average. The rainiest month was February, with 208 millimeters, 8.18 inches. August and June had no rain, and July had only a trace.

The greatest precipitation on any rainfall day was 36 millimeters, 1.40 inches, on December 16. The greatest amount in the 24 hours ending at an observation hour was 44 millimeters, 1.72 inches, to the morning observation on December 17. The average amount of precipitation per day with measurable precipitation was 9 millimeters, 0.35 inch; December had the greatest average, 12 millimeters, 0.42 inch. The average amount per day with significant precipitation was 10 millimeters, 0.39 inch; May and February had the highest averages, 13 millimeters, 0.51 inch.

With the exception of 0.5 millimeter, 0.02 inch, the rain was the result of more or less well defined cyclones, of which 40 were recognized. The average precipitation per cyclone with rain was 19.4 millimeters, 0.77 inch. The rainiest cyclones were those of December 15–18 and January 26–30, each of which had 66.0 millimeters, 2.60 inches, of rain. The longest cyclone was seven days in length, January 19 to 25. The study of precipitation by cyclones was made solely with a view to assigning the rain to the proper cyclone; no attempt was made to study the cyclonic weather of Berkeley from any other angle.

Practically all the wind was from a southerly or westerly direction, but 33 days having prevailing winds from the north and east. The amount of north and east wind was slightly greater at the observation hours. One day was recorded as calm, but no movement of wind was observed at 94 observation hours, 13 per cent of all observations. Summer wind conditions prevailed on 53 per cent of the days, varying from 100 per cent in July to 16 per cent in January. Winter wind conditions prevailed on 15 per cent of the days; the maximum was 39 per cent in December; the minimum was none in July and August.

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